# NICKEL

By Peter H. Kuck

The nickel supply picture changed drastically when a world class nickel-copper-cobalt deposit was delineated in October 1994 at Voisey Bay, Labrador. The near-surface sulfide deposit has at least 32 million metric tons (mt) of resources averaging 2.83% nickel (Ni), 1.68% copper (Cu), and 0.12% cobalt (Co). The Voisey Bay discovery, together with the modernization of operations at Sudbury, Ontario, and the launching of the Raglan Mine in northern Quebec, should keep Canada in the forefront of nickel suppliers far into the 21st Century. The discovery also has had a psychological effect on consumers, lessening their concerns about midterm shortages of nickel and encouraging use of the element in new applications.

Russia, the world's largest producer of nickel, continued to privatize and restructure all of its nickel mining and smelting operations. In 1994, RAO Norilsk Nickel accounted for 90.5% of total Russian production. Efforts were underway to modernize the Pechenga smelter on the Kola Peninsula. Scandinavian environmentalists have blamed the smelter—one of three operated by Norilsk—for much of the sulfur dioxide ($SO_2$) found in the air over Lapland. Russian officials have awarded the modernization contract to a Norwegian-Swedish engineering consortium. Groundbreaking was scheduled to begin in 1996. The Norwegian and Russian Governments have agreed to loan Norilsk Nickel almost one-half of the $258 million required for the project.

In December 1994, Sherritt, Inc., and the Government of Cuba formed a joint venture to refine and market nickel mined at Moa Bay. The joint venture immediately began drawing up plans to modernize the entire Moa Bay operation. The bulk of the sulfide precipitate was being shipped to Sherritt's refining complex at Fort Saskatchewan, Alberta.

The price of nickel metal on the London Metal Exchange (LME) gradually recovered, after bottoming out at a 6-year low in September 1993. The price rose steadily throughout 1994, spurred by increased production of stainless steel in the Far East and Western Europe. The price rise occurred in the face of substantial exports of both primary and secondary nickel from Russia. It also ran counter to the buildup of stocks in LME warehouses. LME stocks reached a record high of 151,254 mt on November 24, 1994. In less than a month, though, stocks began to drop off and continued to decline throughout the first half of 1995. In the last few years, financial institutions and commodity investment funds have become increasingly involved in the LME nickel market. Their speculative actions may account for the price paradoxes observed in 1994.

Mine development or expansion projects were underway in Manitoba, Ontario, Quebec, Brazil, Indonesia, New Caledonia, Venezuela, and Western Australia. In addition to Labrador, exploration teams were active in Cuba, Finland, Greenland, the Ivory Coast, South Africa, Russia, and Tanzania.

Apparent U.S. demand for primary nickel increased almost 10% between 1993 and 1994. U.S. demand for stainless steel was up even more substantially, with a large part of the increase being met by imports. Imports of hot-rolled plate, for example, were up 24%. Allegheny Ludlum, one of the larger U.S. stainless producers, was hamstrung by a 10-week strike. Several other stainless producers were in the midst of a restructuring and were unable to increase output. Stainless steel production has plummeted in Russia because of that country's ongoing economic restructuring. In other parts of the world, though, stainless production has been steadily growing. Capacity is being added in the Republic of Korea, South Africa, and Taiwan. Stainless steel now accounts for about 63% of primary nickel demand in the Western World.[1]

Demand for nickel by battery manufacturers also is growing, although the tonnages involved are an order of magnitude smaller than those for stainless steel. Rechargeable nickel-cadmium and nickel-metal hydride batteries are in strong competition with one another for hand-held powertools, laptop computers, cellular telephones, and camcorders. Peugeot SA of France was gearing up to produce electric vehicles (EV's) on an extended basis. The new vehicles were to be powered by nickel-cadmium batteries made by SAFT S.A.

## Legislation and Government Programs

***Cuban Embargo.***—For more than 50 years, relations between Cuba and the United States have been intertwined with the island's nickel industry. In December 1994, the situation became even more complicated when Sherritt and the Cuban Government formed a joint venture to mine, refine and market nickel and cobalt from Moa Bay. The nickel-cobalt mining and processing complex at Moa Bay has been a particular source of contention between the U.S. and Cuban Governments. The Moa Bay facilities were expropriated without compensation from the Freeport Nickel Co. in August 1960. Freeport's successor, Freeport-McMoran Inc., continues to operate out of New Orleans, LA, and still holds claim to the complex, in Holguín Province.

The Cuban Government and Sherritt are equal partners in the Moa Bay venture. The day-to-day interests of the Cuban Government are handled by General Nickel (La Compania General de Niquel S.A.), a parastatal enterprise that also manages the Nicaro, Punta Gorda, and Las Camariocas nickel operations. Like Moa Bay, all three are in Holguín Province. General Nickel replaced Union Empresas del Niquel in 1994 and reports directly to the Ministry of Basic Industries. *(See Cuba section of this review.)*

The vertically integrated joint venture oversees three subsidiaries: Moa Nickel S.A., The Cobalt Refinery Company Inc., and The International Cobalt Company Inc. (ICCI). All three operate collectively as part of Sherritt's Commodity Metals business, but each is a separate 50-50 partnership between General Nickel and Sherritt.

The joint venture was formed to (1) provide a secure source of feed for Sherritt's Fort Saskatchewan refinery in Alberta, and (2) accelerate modernization and expansion of the Cuban nickel industry. None of the venture's production can be marketed in the United States because of the U.S. embargo against Cuba. Importation of Cuban nickel is prohibited under the Cuban Assets Control Regulations, 31 CFR, part 515.

Sherritt has stated that its three business units are operating in compliance with the laws of Canada, which has full economic and trade relations with Cuba. Company officials also believe that Sherritt is complying with applicable U.S. laws because the joint venture does not sell any of its products in the United States.

***Environmental Regulations.***—On

September 19, 1994, the U.S. Environmental Protection Agency (EPA) set final universal treatment standards for a number of wastes that contain nickel mixed together with other regulated hazardous metals (e.g., beryllium, cadmium, chromium, or lead).[2] These wastes are part of a much larger group of wastes regulated under the Resource Conservation and Recovery Act (RCRA). EPA issued the new standards to eliminate confusion about the handling, treating, and disposal of wastes of different origins. The standards apply to "listed" wastes, and not to "characteristic metal" wastes, which have separate standards. Nickel-bearing wastes falling into the "listed" category include: Wastewater treatment sludges from electroplating operations (Waste code F006); Leachate [liquids that have percolated through land disposed wastes] (F039); and Emission control dusts and sludges associated with the production of steel in electric arc furnaces (K061).

On February 11, 1993, EPA proposed new streamlined regulations governing the collection and management of spent nickel-cadmium (Ni-Cd) batteries, mercury-containing thermostats, and certain other widely generated hazardous wastes. The agency solicited additional comments from the general public on June 20, 1994, and was to put the regulations (40 CFR part 273) into effect on May 11, 1995.[3] The new regulations are designed to encourage environmentally sound recycling of Ni-Cd batteries and keep them out of the municipal waste stream. No distinction is made on the basis of battery size, or between "wet" and "dry" batteries (i.e., batteries with liquid vs. nonliquid electrolytes). The package of regulations is known as the "Universal Waste Rule."

On February 2, 1994, the Ozone Transport Commission (OTC) petitioned EPA, requesting that New England and the Middle Atlantic States be allowed to follow California's lead on vehicular pollution-control standards. Adoption of the standards would help the northeastern United States comply with national ambient air quality standards. The OTC, established in 1991 under Section 184 of the Clean Air Act Amendments of 1990, is an interstate agency responsible for reducing ozone levels in the Northeast.

The California-style program would allow individual States in the region to mandate the sale of advanced technology vehicles (ATV's) if Federally legislated air quality goals cannot be met. Zero-emission vehicle sales mandates have been controversial and, in some cases, have led to litigation. The New York regulations have been upheld by the Courts, but the ones for Massachusetts were still being contested. EPA was to have ruled on the OTC petition by November 10, but let the deadline pass after receiving a deluge of comments. At the present time, only EV's can meet California's zero tailpipe emission requirement. California's program is to take effect in late 1997.

The OTC petition was important to the nickel industry because EV's powered by rechargeable nickel-based batteries could be used to meet part of the sales mandates proposed for those portions of the Northeast with the severest air pollution problems. The battery pack of a typical EV could conceivably contain 40 to 170 kilograms of nickel depending upon its design and battery chemistry.

Various State environmental agencies and automobile manufacturers have met in search of alternatives. The manufacturers have offered to begin selling cleaner, low-emission gasoline-powered vehicles nationwide by 1999. Industry representatives claimed that the "49-State Car" would satisfy all of the basic requirements of the Clean Air Act. Several compromises were proposed. One proposal called for State and Federal agencies to acquire EV's, vehicles that run on compressed natural gas, and other ATV's for their fleets. ATV's would be offered for sale at the retail level in the region beginning in 2002.[4]

Finally on December 19, EPA tentatively approved the OTC petition, allowing the 12 States and the District of Columbia to impose California-style limits on vehicle emissions.[5] The OTC was continuing its discussions with the automobile manufacturers in an effort to make the program better and more acceptable to the entire automobile industry.

***Defense Stockpile Sales.***—The Defense Logistics Agency (DLA) continued to sell nickel metal from the National Defense Stockpile (NDS). The Government had 33,760 mt of nickel in inventory when the sales started on March 24, 1993. The bulk of the material was purchased during the Korean War or the 5-year period immediately following the war. All 33,760 mt was cathode except for 399 mt contained in 520 mt of oxide of Cuban origin.

Nickel had been included in the stockpile since the beginning of World War II. In 1941, nickel was one of the first metals to be placed on a restricted-use basis. The metal was desperately needed to make gun steels and remained in short supply throughout the war. However, in October 1992 the Bush Administration, together with the Congress, decided that the Government no longer needed to hold nickel and authorized disposal of the entire inventory. The ongoing sales are part of a much larger downsizing of the stockpile approved under the Defense Authorization Act of 1992 (Public Law 102-484).

By the beginning of 1994, uncommitted stocks had shrunk to 31,182 mt. A total of 4,794 mt were turned over to purchasers in 1994, leaving uncommitted stocks of 25,470 mt on December 31. Total yearend stocks also included 1,287 mt of committed material. An additional 7,486 mt of cathode was auctioned off during the first 9 months of 1995. It will take at least 2 years to dispose of the remaining nickel at the currently authorized sales rate.

**Production**

The nickel mining and smelting complex near Riddle, OR, was idle all of 1994. The complex is owned and operated by the Glenbrook Nickel Co. ) a 50-50 venture of Cominco American Inc. and Cominco Resources International Ltd. Glenbrook's management shut down the operation in August 1993 shortly after the LME cash price dropped below $2.50 per pound. However, when nickel prices recovered in late 1994, the company decided to resume production. Startup was scheduled for April 1995.[6]

The port facility at Coos Bay, the mine on Nickel Mountain, and the ferronickel smelter at the base of the mountain were all described in detail in a 1993 journal article by Kerry Spickelmier.[7] Glenbrook had been using lateritic ore from both New Caledonia and Nickel Mountain as feed. The New Caledonian ore imported in 1991-93 typically contained 2.2% to 2.4% Ni on a dry basis and was significantly richer than the 1.0% to 1.25% material being mined on Nickel Mountain. The recently renovated smelter has a capacity of 16,000 metric tons per year (mt/a) of Ni in ferronickel. The existing process requires ferrosilicon, but produces ferronickel with a considerably higher Ni content (48% to 52%) than most competing ferronickel products.

The International Metals Reclamation Co., Inc. (INMETCO) continued to produce nickel-chromium-iron alloy at its metals recovery facility in Ellwood City, PA. The facility was set up in 1978 to reclaim chromium and nickel from emission control dusts, swarf, grindings, and mill scale—all generated by the stainless steel industry. The plant later was modified to process filter cakes, plating solutions, spent Ni-Cd batteries, and a variety of other recyclable ferrous metal-bearing wastes. In 1993, INMETCO produced 22,196 mt of chromium-nickel-iron alloy from 58,000 mt of solid waste and 710,000 gallons of liquid waste. The 58,000 mt of solids included 1,900 mt of consumer and industrial Ni-Cd batteries.[8]

In May 1994, INMETCO acquired key cadmium recovery technology from Saft Nife AB. That same month, INMETCO awarded a

contract to design and construct a full-scale cadmium recovery unit at Ellwood City. The new unit will allow cadmium metal to be recovered onsite, allowing more Ni-Cd batteries to be fed into the operation.

**Consumption**

Demand for primary nickel in the Western World grew substantially in 1994 and was estimated to be about 779,000 mt — an all time high.[9] The tonnage was about 15% more than the previous record of 674,000 mt set in 1993. U.S. apparent consumption of primary nickel was 134,000 mt, or about 17% of Western demand. U.S. industry consumed an additional 59,000 mt of nickel in scrap. Both U.S. and world demand continued to be driven by the stainless steel industry, which accounted for 38% of primary nickel demand in the United States and more than 60% of equivalent world demand. *(See tables 2 through 4 and figure 2.)*

Since 1991, major restructuring, adoption of more efficient work practices, and the introduction of new technology have improved the competitiveness of the U.S. stainless and specialty steel industry. Production of raw stainless and heat-resisting steel in the United States increased slightly to 1.83 million mt and was 3% more than the corresponding figure for 1993.[10] Nickel-bearing grades accounted for 1.20 million mt, or 65% of the production tonnage. Net shipments of all types of stainless totaled 1.56 million mt.[11] Shipments of sheets and strip rose 15% to 1,125,137 mt, breaking the record of 981,677 mt just set in 1993. This category has been steadily increasing since 1989. The next largest category was plate [flat product 4.8 millimeter (3/16 inch) or more in thickness]. Shipments of plate were 185,115 mt, 5% more than that of 1993. Together, plate and sheet accounted for 84% of total net shipments, compared with 83% in 1993.

On April 1, 1994, the United Steelworkers of America struck Allegheny Ludlum Corp., one of the larger stainless steel producers in the United States.[12] The strike lasted 10 weeks and idled 3,500 workers. Operations were crippled at six of the company's plants, including the melt shop at Brackenridge, PA. The strike ended on June 9, with steel shipments returning to normal levels by the fourth quarter.

The operations of Jessop Steel were successfully integrated into Allegheny Ludlum, despite the strike. Allegheny Ludlum acquired Jessop on November 10, 1993, as part of Allegheny Ludlum's buyout of Athlone Industries, Inc. Jessop's melt shop at Washington, PA, was closed and all of its melting work was transferred either to the nearby Brackenridge and Natrona meltshops or to Lockport, NY.[13]

In 1994, U.S. consumption of primary nickel in superalloys increased 6%, despite problems in the aerospace industry. Sales by the aerospace industry fell 9% to $113 billion.[14] Combined aircraft and missile purchases by the U.S. Department of Defense declined for the seventh consecutive year. Purchases of civil aircraft, engines, and parts by commercial airlines and foreign governments were down 22%. Jet engine manufacturers, significant consumers of nickel-chromium-cobalt and nickel-chromium-iron alloys, were working aggressively to cut costs. The Boeing Co. and McDonnell Douglas Corp. continued to work off a backlog of orders received between 1988 and 1990 for civil jet transport. However, this backlog has been steadily shrinking over the last 4 years. Only 79 net orders for large civil jet transports were received in 1994, compared with 309 shipped. On December 31, 1994, the two companies had a combined backlog of 1,126 aircraft, down from 1,356 at yearend 1993 and 2,138 at yearend 1990.

Domestic consumption data for nickel metal and its compounds are developed by the U.S. Bureau of Mines from a voluntary survey of U.S. operations. Sixty-four consumers participated in the Bureau's monthly canvassing program. An additional 123 consumers returned the 1994 annual survey forms, for a total response of 187. The consolidated consumption data are shown in tables 3 through 5.

**Stocks**

The combined stocks of primary nickel maintained in the United States by foreign producers and metal-trading companies with U.S. sales offices declined 35% during the year. At yearend, these stocks represented 28 days of apparent primary consumption. The stocks held by domestic consumers are given in table 5.

In recent years, LME stocks have far exceeded U.S. consumer stocks. On December 31, 1994, LME warehouses held 148,392 mt of nickel metal, of which 148,230 mt or 99.9% was in the form of cut cathodes. The remaining 0.1% consisted of briquets and a limited amount of pellets. The inventory on the 31st was less than 2% off the all-time record high of 151,254 mt reached a month before on November 24.

Although the LME has 18 warehouse sites scattered around the world that are authorized to hold nickel, most of the material is being stored in Rotterdam. The surge in exports from Russia caused stocks in Rotterdam to mushroom during 1994. At closing on November 24, the Rotterdam depots had 141,060 mt on warrant, or 93% of total LME stocks. Two years earlier, on November 26, 1992, Rotterdam had 60,066 mt on hand, with stocks at all of the remaining LME locations totaling only 2,610 mt.

**Prices**

Nickel prices gained considerable ground between mid-1993 and the end of 1994. *(See figure 1.)* In the summer of 1993, the LME cash price was still under pressure from lingering recessionary forces in Japan, the United States, and Western Europe. For more than 2 years, the nickel supply in the Western World had significantly exceeded demand, gradually forcing prices downward. Russian stainless production had plummeted and the value of the ruble was shrinking, encouraging Norilsk Nickel to export the bulk of its nickel production to the West. At this point, market forces forced prices further downward. The LME cash price finally bottomed out on September 30, 1993, hitting a 6-year low of $4,012 per mt ($1.820 per pound) for the day.

Prices slowly improved during the winter of 1993 as demand for stainless steel began to pick up. By the beginning of 1994, prices had partially recovered and were still rising. The average LME cash price for the first week in January was $5,215 per mt ($2.365 per pound). Prices continued to climb throughout the spring of 1994. On May 27, the weekly average reached $6,462 per mt ($2.931 per pound). Prices took a small downturn in August, but quickly recovered and resumed their climb. The last weekly price (for the week ending December 30) was $8,742 per mt ($3.965 per pound). The average annual price for 1994 was $6,340 per mt ($2.876 per pound). This was almost 20% higher than the 1993 average of $5,293 per mt ($2.401 per pound).

Prices did not peak until late January 1995. The average cash price for the week ending January 27 was $10,072 per mt ($4.569 per pound). Since then, prices have been volatile, fluctuating between $6,900 and $9,800 per mt of nickel ($3.13 and $4.45 per pound). Some analysts attributed the volatility to the increasing role being played in the nickel futures market by commodity funds, financial institutions, speculators, and other segments of the investment community.

**Foreign Trade**

U.S. net import reliance as a percentage of apparent consumption was 64% in 1994. The figure was slightly higher than the 1993 percentage because of the extended shutdown of the Glenbrook smelter and a 16% increase in

imports of ferronickel. Imports accounted for almost 100% of primary supply in 1994, if Government stockpile sales are excluded. *(See tables 8 and 9.)* Canada, as usual, supplied most of the imported material. A significant part of the nickel imported from Norway, the second largest source, was also of Canadian origin.

U.S. imports of Russian cathode dropped 30% between 1993 and 1994. In 1994, the United States imported 4,659 mt of cathode and 640 mt tons of powder and/or flake directly from Russia. Importers also brought in 790 mt of Russian nickel contained in ferronickel and 27 mt contained in primary chemicals. These figures do not include material that may have been recovered in Norway from Russian matte and later exported to the United States.

Increased demand for stainless steel in the Far East and Western Europe caused prices for both primary nickel and nickel-bearing scrap to rise worldwide. As a result, U.S. exports of stainless steel scrap rose 26% between 1993 and 1994. Most of the additional tonnage went to meltshops in the European Union. Exported stainless scrap contained an estimated 22,396 mt of Ni, up from 17,849 mt in 1993. These figures are based on the assumption that stainless scrap has been averaging 7.5% Ni since 1989, when the changeover to the Harmonized Tariff System took effect. *(See tables 6 and 7.)*

On September 8, 1994, the U.S. International Trade Commission (ITC) launched an investigation of Japanese-made nickel/metal hydride (Ni-MH) anode materials and batteries. In August, the Ovonic Battery Co., Inc. (OBC) and Energy Conversion Devices, Inc. petitioned the ITC to bar the importation and sale of Ni-MH batteries from Japan, claiming that the major Japanese battery manufacturers were infringing on OBC's patent (U.S. Letters Patent 4,623,597) — violating section 337 of the Tariff Act of 1930.

OBC is a subsidiary of Energy Conversion Devices; both companies are in Troy, MI. The complaint named three prominent Japanese companies together with their U.S. subsidiaries: Sanyo Electric Co. Ltd. of Hyogo, Toshiba Battery Co. Ltd. of Tokyo, and Yuasa Corp. of Tokyo.

Rechargeable Ni-MH batteries are being increasingly used in portable consumer electronics, such as laptop computers, pagers, cellular telephones, and video cameras. According to some industry experts, the market for Ni-MH consumer batteries is growing at more than 15% per year.

**World Review**

***Australia.—***Western Mining Corp. Holdings Ltd. (WMC), one of the four largest nickel producers in the Western World, continued to expand production capacity. At the end of 1994, the company was ready to start up its new Mount Keith Mine. The open pit operation is in the Greenstone Belt of Western Australia, about 90 kilometers (km) north of Agnew. Today, the $320 million complex is one of the larger metal mines in Australia.

WMC was planning to extract 210 million mt of ore, averaging 0.58% Ni, from Mount Keith over the next 20 years. The on-site concentrator is designed to handle 18,000 mt of sulfide ore per day, which equates to about 28,000 mt/a of Ni in concentrate.

Construction crews have been on-site since March 1993. Over 75% of the construction work on the concentrator and associated infrastructure had been completed by June 1994.[15] At that point in time, the open pit was more than 60 meters (m) deep, exposing part of the orebody. The principal contractor was Leighton Holdings Ltd., a construction and civil engineering company based in New South Wales. Between 700 and 1,000 construction workers were employed on the project in late 1994. However, only 231 employees will be needed to operate the mining complex.

The concentrator was commissioned in December and began shipping concentrates a month later. Half of the concentrate was to go to WMC's smelter at Kalgoorlie; the rest, to the Harjavalta smelter of Outokumpu Oy in Finland. WMC also recently upgraded and expanded both its Kalgoorlie smelter and Kwinana refinery.

Anaconda Nickel NL was in the early stages of evaluating the Murrin Murrin deposit.[16] The deposit is about 150 km southeast of Agnew in Western Australia. BHP Engineering Pty. Ltd., Sherritt, and H. A. Simons Ltd. of Vancouver, BC, have agreed to participate in the prefeasibility studies. According to Anaconda officials, the deposit has at least 66 million mt of lateritic ore grading about 1.14% Ni and 0.07% Co. A pressure acid-leaching plant would be built on-site to extract the nickel and cobalt directly from the ore. The Murrin Murrin operation would produce 31,000 mt/a of nickel and 2,500 mt/a of cobalt.

In March, the Government of Western Australia approved the construction of a 1,380-km-long natural gas pipeline from Yarraloola on the northwest coast through the Pilbara to the nickel smelter at Kalgoorlie.[17] The pipeline would go through the Goldfields region and pass close to Wiluna, Mount Keith, and Leinster. On March 23, the Premier of Western Australia signed an agreement with the Goldfields Gas Transmission Joint Venture (GGTJV), setting conditions for nondiscriminatory third-party access to the gas and establishing key design parameters. GGTJV is a joint venture of WMC, BHP Minerals Pty. Ltd., and Normandy Poseidon Ltd. Most of the gas will come from the offshore Griffin or North Rankin gas fields on the North West Shelf. However, some may also come from the onshore Tubridgi field.

Construction of the pipeline was to start in July 1995 and would take about a year to complete. Delivery of gas to Kalgoorlie was scheduled to begin in August 1996. The Government and consortium are hoping that the A$400 million pipeline will stimulate additional investment in the region's mining industry. Part of the gas would be available for mineral extraction and processing, encouraging existing metal producers along the route to build downstream processing facilities that would add value to their products. Cheaper energy could spur development of Bulong, Anaconda, and several other nickel laterite deposits.[18]

***Brazil.—***RTZ Corp. was planning to spend $233 million to develop the Fortaleza deposit in the State of Minas Gerais.[19] RTZ acquired the rights to the site in 1989 as part of a packaged purchase of projects from British Petroleum. An open pit mine would be developed first, followed by an underground complex. The nickel-copper-cobalt sulfide concentrates would be smelted on-site using the flash smelting process developed by Outokumpu Oy. An adjoining electrolytic refinery would produce about 10,000 mt/a of cathode. The bulk of the cathode would go to the Brazilian stainless steel industry.

***Canada.—***In September 1993, an exploration team working for Diamond Fields Resources Inc. discovered significant nickel-copper-cobalt mineralization in a remote area of the Labrador coast at a point west of Voisey Bay. Initial core drilling of the prospect in late 1994 revealed a massive sulfide ore body more than 100 m thick. The Voisey Bay deposit reportedly is the largest base metal discovery in Canada in more than 30 years. The discovery site is 35 km southwest of the town of Nain and about 350 km northwest of Goose Bay.

Up until the discovery, Diamond Fields had been a small mining company exploring primarily for diamonds. The company had done little work in northern Labrador ) most of its experience being in southern Africa, Sierra Leone, and the Northwest Territories. Diamond Fields is headquartered in Vancouver, BC.

Less than 1% of the 1,800 square kilometers ($km^2$) of claims has been drilled to date. Although the massive sulfide deposit is in a

remote part of northeastern Labrador, it is only 10 km from a natural deep-water harbor. The deposit lies close to the surface, permitting inexpensive open pit mining.

Exploration geologists became interested in the site after identifying an electromagnetic and magnetic geophysical anomaly in an area riddled with large sills and dikes. The anomaly is at least 7 km in length. The four discovery holes (VB-94-01 to 04) penetrated a thick east-west trending gabbroic dike containing disseminated, semimassive, and massive sulfide mineralization. The best of the four holes (VB-94-02) reportedly intersected 71 m of ore assaying 2.23% Ni, 1.47% Cu, and 0.123% Co.[20] Since then, additional geophysical surveying has revealed that the anomaly widens to the east, where it takes on an ovoid shape. Crews were preparing to drill the ovoid feature at the beginning of 1995.

More than 160 holes have been drilled on the property since the original discovery. According to Teck Corp., which now holds a 10.4% interest in Diamond Fields, the near-surface deposit has at least 32 million mt of resources averaging 2.83% Ni, 1.68% Cu, and 0.12% Co.[21] If the preliminary findings are correct, Voisey Bay would be bigger and richer than Raglan. The ore body has a wine-glass shape in section and is roughly 450 m in length. In plan view, it is 300 m wide at its thickest point. An airborne geophysical survey was being conducted over the entire 1,800 $km^2$ of claims held by Diamond Fields and its lessor, Archaean Resources Ltd. Archaean will earn a 3% net smelter royalty. *(For additional information and detailed assay results, see references cited in footnotes 22, 23, and 24.)*

Falconbridge Ltd. has decided to develop its Raglan deposit at the northern tip of the Ungava Peninsula. Work was to begin as soon as ongoing negotiations with the Provincial Government of Quebec were completed. A few issues involving infrastructure funding, environmental permitting, and taxation still needed to be resolved. Falconbridge also had to finalize its agreement with the Makivik Corp., which represents the local Inuit people.[25]

Falconbridge was planning to spend C$486 million to bring the deposit into production by mid-1998. A sulfide concentrate would be produced on-site at Katinniq and trucked about 65 km to Deception Bay, PQ, where it would be transshipped by vessel to the company's smelter at Sudbury, ON. At Sudbury, the concentrate would be converted into matte. From Sudbury, the matte would go to the company's Nikkelverk refinery at Kristiansand, Norway. The capacity of the 64,000-mt/a Nikkelverk operation was being increased to 80,000 mt/a of Ni at a cost of C$31 million to handle the additional matte.

According to Falconbridge officials, the Raglan deposit has 18.1 million mt of reserves, averaging 3.13% Ni and 0.88% Cu. Of the 18.1 million mt, 4.5 million are proven. Falconbridge was planning to produce 20,000 mt/a of Ni in concentrate over the first 15 years of operation. The deposit was discovered in the 1930's but had been passed over on several occasions because of its extreme northern location. Falconbridge has had control of the property since 1966.

In October, Inco inaugurated a revolutionary facility at Sudbury that produces electrode substrates from nickel carbonyl. The new facility is located at the Copper Cliff nickel refinery and primarily will make nickel foam for rechargeable batteries, including batteries for EV's.

***China.***—On December 8, 1994, Inco announced that it had entered into a joint venture with Jinchuan Non-Ferrous Metals Corp. to produce nickel salts for the Asian market. Jinchuan is, by far, the largest nickel producer in China and accounted for 88% of the country's total nickel output in 1993. The parastatal company is a subsidiary of China National Non-Ferrous Metals Industry Corp. (CNNC). Jinchuan has been expanding its operations in Gansu Province and was capable of producing 40,000 to 50,000 mt/a of cathode in mid-1995.

The joint venture planned to construct a nickel chemical plant in the Shanghai area at a cost of about $10 million. Inco would have a 65% share in the venture; Jinchuan, 35%.[26]

***Colombia.***—In the fall of 1994, Gencor Ltd. acquired Billiton BV from the Royal Dutch/Shell Group, and with it, Billiton's 47% interest in the Cerro Matoso ferronickel operation. The remaining shares are held by Cia. de Niquel Colombiano S.A. (5%) and an agency of the Colombian Government ) Instituto de Fomento Industrial (48%). The equity in Cerro Matoso was one of several lesser mining and smelting interests included in the sale of Shell's bauxite and aluminum holdings. The Billiton acquisition reportedly was part of Gencor's plan to focus on its core mining businesses and internationalize more of its holdings. Since 1993, Gencor has become increasingly involved with nickel because of its ties to the Columbus Stainless Steel Project and Impala Platinum Holdings Ltd. *(See section on South Africa.)*

In 1994, Cerro Matoso produced 20,833 mt of nickel contained in ferronickel bars and granules. The latest statistics released by the INSG indicate that the company exported 20,501 mt on a contained basis in 1994, 55% of which went to Europe.

***Cuba.***—On December 2, 1994, General Nickel of Cuba and Sherritt announced that they had formed a joint venture to mine, refine, and market nickel and cobalt. Negotiations between the two partners had been underway for more than 6 months.

General Nickel mines limonitic laterite ores in the eastern part of Holguín Province and, until the joint venture was formed, operated the nickel-cobalt processing plant at Moa Bay. The Government of Cuba endorsed the joint venture, which has three separate subsidiary corporations.

The first corporation, Moa Nickel S.A., became responsible for all of the mining and beneficiation operations at Moa Bay. However, Cuba's two other processing plants)Nicaro and Punta Gorda)are not part of the joint venture.[27] The second corporation, The Cobalt Refinery Co., runs the recently upgraded nickel-cobalt refinery at Fort Saskatchewan, Alberta. The refinery is now able to produce 25,000 mt/a of nickel in metal powder and briquets. The third corporation, ICCI, markets and sells the output of the Canadian plant in Europe and Asia. The Government of Cuba has granted the venture mining concessions with more than 60 million mt of limonitic ore. About 80% of these reserves are proven, according to Sherritt officials. The ore typically averages about 1.3% Ni, 0.1% Co, 3.7% $SiO_2$, and 64% $Fe_2O_3$ after drying. The concessions will allow the Moa plant to operate for at least 25 years. The Government also granted the venture more than 15,000 hectares of additional reserves which could extend the life of the operation to a total of 50 years.

The joint venture will spend approximately C$150 million (US$108 million) upgrading and expanding the Moa facilities. The Cuban plant was built for the Freeport Nickel Co. between 1957 and 1959 at a cost of $61.5 million and has been in almost continuous production since then. The Moa operation uses a pressurized acid leach process to extract the two metals and was producing about 13,000 mt/a of nickel in sulfide precipitates. The upgrading, expected to take 3 to 5 years, would raise the capacity of the operation to 24,000 mt/a. The process is relatively efficient, recovering more than 90% of the nickel, but consumes large amounts of sulfuric acid. The sulfuric acid is neutralized with coral mud midway through the process and converted to waste gypsum. Disposal of residual acid reportedly has created environmental problems for the Cubans. Sherritt was hoping to solve most of these problems with new proprietary technology developed by the company.

Sherritt was planning to invest at least $109 million to upgrade the facilities at Moa Bay. Roughly one-third of the money would be used

to replace the three existing acid plants with a single modern unit. New materials handling equipment also was needed.[28]

In a related development, WMC agreed in principle to establish a joint nickel-cobalt venture in Cuba with Commercial Caribbean Nickel S.A. (CCN). The announcement was made by WMC's Board of Directors on September 21, 1994. The joint venture with the Cuban parastatal company would explore and, if commercially viable, develop the Pinares de Mayari West deposit. The laterite deposit, also in Holguín Province, reportedly contains at least 200 million mt of ore grading 1% Ni and 0.1% Co. WMC would earn a 65% share in the project by funding a delineation drilling program, metallurgical test work, and a feasibility study.

Gencor also signed a letter of intent with the Government of Cuba to evaluate and, if economically feasible, develop the San Felipe lateritic nickel deposit in central Camaguey Province.[29] A formal agreement establishing a joint venture was expected to be concluded in 1995. The San Felipe project would be the first nickel mining operation outside Holguín Province. The proposed joint venture also would be responsible for developing a nearby gold-copper deposit. Malecon Minerals & Metals Holdings Ltd., a wholly owned subsidiary of Gencor, would oversee both projects. Gencor would have a 75% interest in the proposed nickel project; the Cuban Government, 25%. The gold-copper project, though, would be a 50-50 venture.[30]

The director of Geominera S.A., a parastatal agency of the Cuban Government, told reporters in Havana that Gencor was prepared to invest more than US$300 million in developing both the nickel and gold deposits and constructing facilities for processing the two ores. Gencor reportedly has had exclusive rights to explore for both nickel and gold in the San Felipe district for some time. The crude output of nickel and cobalt would be refined outside Cuba.

The Cuban Government created Geominera so that the Government could enter more easily into joint ventures with foreign companies involved in exploration and mining. The parastatal company is part of the Ministry of Basic Industry. Parastatal joint ventures of this type have been permitted since the enactment of Legislative Decree No. 50 in February 1982.

***Dominican Republic.***—In 1994, Falconbridge Dominicana, C. por A., produced 30,800 mt of Ni in ferronickel.[31] More than 90% of the ferronickel was in the form of ferrocones, a product resembling a large metallic gumdrop and weighing about 125 grams. The new Loma Ortega Mine was in full production and was supplying about 15% of the feed for the Bonao smelter. Loma Ortega lies outside the original mining area and is about 50 km from the smelter.

***Finland.***—Outokumpu Metals & Resources Oy (OMR) was in the midst of a restructuring and decided to halt mining at its Vammala Mine in Turku-Pori Province because of declining ore reserves.[32] The Vammala Mine had been in operation since 1978 and produced 7.4 million mt of ore, averaging 0.69% Ni and 0.43% Cu. Most of the 60 employees at Vammala were reassigned to neighboring gold operations.

OMR has only one nickel mine still operating in Finland)the Hitura Mine near Ainastalo. According to company records, the Hitura Mine had 1.1 million mt of proven and probable reserves, averaging 0.66% Ni, at the end of 1994. The mine had an additional 4.47 million mt of indicated and inferred resources containing 0.81% Ni.

The Enonkoski Mine, OMR's third nickel operation, was officially closed in December 1994. The mine is near Karvila and Savonlinna in the southeastern part of Finland and was the largest of the three, with a capacity of 7,200 mt/a of nickel in concentrate. During its 9 years of operation, the Enonkoski Mine produced 6.7 million mt of ore, averaging 0.76% Ni and 0.22% Cu. The mine reportedly still has 0.61 million mt of reserves remaining, but they contain only 0.37% Ni and 0.10% Cu.

Outokumpu was in the process of expanding and modernizing its Harjavalta smelting and refining complex. The modernization will raise the production capacity of the complex to 32,000 mt/a of nickel briquets and cathode and 160,000 mt/a of blister copper. In 1994, Harjavalta produced 15,900 mt of nickel and 98,200 mt of blister copper. Nickel production costs were expected to drop 20% as a result of the improvements.

Both Finland and Russia are interested in promoting development in the sparsely populated Arctic. The Government of Finland was soliciting bids to develop the Kevitsa nickel-copper deposit in Lapland. The first round of bids was due on February 2, 1995. The Kevitsa deposit was discovered by the Finnish Geological Survey about 1991 near the town of Sodankyla. More than 300 exploratory holes have been drilled to date. The deposit covers at least 10 hectares (25 acres) and occurs in a ultramafic layered intrusion (mostly olivine pyroxenites) of Early Proterozoic Age. The Ni/Cu ratio ranges from about 0.6 to 0.9. Platinum group metals, gold, and cobalt also are enriched in the ore.

***Indonesia.***—In November 1994, P.T. International Nickel Indonesia (P.T. Inco) announced plans to increase the capacity of its mining and smelting complex on the island of Sulawesi by 50%. The expansion would take 5 years and cost $500 million. The annual capacity of the Soroako smelter would be raised from 45,400 mt of Ni in matte to about 68,000 mt. The expansion would involve installation of a fourth electric furnace at Soroako and construction of additional hydroelectric generating capacity at the company's powerplant on the Larona River.

P.T. Inco decided to move ahead with the expansion after the Government of Indonesia agreed in principle to extend P.T.'s Inco's contract of work beyond the year 2008. The contract of work extension was to have been submitted to the Indonesian Parliament for approval sometime in 1995. P.T. Inco currently has mining rights to 218,529 hectares (540,000 acres) of laterite on Sulawesi. Exploration since 1990 has identified additional resources southeast of Soroako, between Pomalaa and Torobulu. The Pomalaa East area contains at least 50 million mt of ore, averaging 1.9% Ni, and may constitute a possible resource of 147 million mt.[33]

P.T. Inco produced a record 45,325 mt of nickel in matte in 1994, up significantly from the 34,353 mt of 1993. The granulated matte averages 78% Ni and is shipped to the Tokyo Nickel Co., Ltd. in Japan for further refining.

P.T. Inco has been operating in Indonesia since 1968 and had 2,066 permanent employees at the end of 1994. An additional 1,100 people were working on-site either temporarily or for contractors. The two principal shareholders are Inco Ltd. of Canada (58.19%) and Sumitomo Metal Mining Co. Ltd. of Japan (20.09%). Another 20.00% is held by public shareholders. The remaining 1.72% is divided between Tokyo Nickel and four other Japanese companies.

***Ivory Coast.***—Falconbridge geologists were investigating several laterite deposits near Mount Nimba on the border with Liberia. To date, their work has focused on three prospects in the Biankouma-Sipilou concession. Together, the three prospects have 54 million mt of ore averaging 2.02% Ni and 0.07% Co.[34] The Sipilou North area has an additional 54 million mt of ore grading 1.80% Ni and 0.10% Co. Preliminary metallurgical tests indicate that ferronickel could be made from the West African ores using the Falcondo process presently employed in the Dominican Republic. The project is part of a joint venture with Trillion Resources Ltd. of Ottawa, Ontario, and the Société d'État pour le Développement Minier de la Côte d'Ivoire.[35]

***New Caledonia.***—In May 1994, Société Métallurgique Le Nickel (SLN) commissioned its new Kopeto 2 Mine near Nepoui.[36] The

open pit mine is about 250 km northwest of the capital of Nouméa. The mine was expected to produce 830,000 mt of lateritic ore annually over the next 15 years and was designed to provide one-third of the feed material required by the company's Doniambo smelter in Nouméa. The garnierite-rich saprolitic ore assays about 2.1% Ni.

The Kopeto 2 Mine is 20 km inland from the coast, at an altitude of about 1,000 m. The area was worked during the 1970's and eventually abandoned. SLN decided to resume mining at the site when 14 untouched ore bodies of garnierite [$(Mg>>Fe, Ni)_3Si_2O_5(OH)_4$] were discovered.

SLN has 10 50-mt dump trucks on-site that haul the garnierite-rich ore to a screening facility. After screening, the ore is slurried and piped 7 km down into the valley to a washing plant and transfer point. Private contractors then truck the washed ore to a storage and reclaiming yard on the coast for transhipment by coastal vessel to Doniambo.

At Doniambo, the ore is blended, partially dried, calcined, and then smelted in one of three electric arc furnaces. The Doniambo smelter produces both ferronickel and a nickel matte. The refined ferronickel averages 29% Ni. The nickel content of the matte is much higher and typically runs about 75% Ni. The matte is cast into ingots and shipped to ERAMET-SLN's Sandouville refinery in northern France for conversion into cathode. In 1994, the Doniambo smelter produced 39,488 mt of Ni in ferronickel and 10,641 mt of Ni in matte.[37]

The opening of the Kopeto 2 Mine created 225 new jobs in a part of the island where unemployment has traditionally run high, and a strong pro-independence movement exists. A 3-year training program was begun in 1993 for the new employees, with $1.33 million provided by SLN and $1.42 million by different agencies of the Province, the French Territory, and the European Community. An additional 50 workers truck ore from the washing plant to the coast or provide other support services on a contract basis.

***Norway.***—Falconbridge Nikkelverk A/S produced 68,000 mt of refined nickel, up 20% from 56,800 mt in 1993.[38]The 68,000 mt figure broke the company's previous production record of 58,700 mt set in 1991. The refinery was recently upgraded and was operating close to its new capacity of 69,000 mt/a. Nikkelverk employees have developed a unique machine for stripping each sheet of electrodeposited nickel off of its starter sheet. The new machine, a first for the nickel industry, was installed in 1994 and should further increase productivity.

***Russia.***—RAO Norilsk Nickel produced 162,500 mt of nickel metal in 1994, along with 300,000 mt of copper metal, 3,600 mt of cobalt metal, and 1,200 mt of cobalt oxide.[39] An additional 10,000 to 16,000 mt of nickel was contained in 24,000 mt of matte shipped to Falconbridge's Nikkelverk refinery in Norway.

The Norilsk Nickel operations were partially privatized in April 1994. The new organization is composed of six, largely independent joint-stock companies: Norilsk Complex, Pechenganickel Complex, Severonickel Complex, Krasnoyarsk Non-ferrous Metals, Gipronickel Institute, and Olenegorsk Mechanical Works. The Norilsk complex had two new underground mines under development in 1994)the Skalisty and the Gluboky.[40] These would supplement the one large open pit and five underground mines that the complex has had in operation for some time. The Norilsk complex is located on the Taimyr Peninsula of north-central Siberia and has its own nickel smelter plus a matte separation plant, a nickel refinery, and a copper refinery.

Pechenganickel had four mines in operation along the border with Norway. Two of the mines, the Tsentralny and Zapadny, are open pits in the Zhdanovskoye deposit. The other two, the Kaula-Kostalvaara and the Severny, are underground operations. All of the concentrates and direct-shipping ore were going to the smelter at Pechenga for processing along with material from Norilsk. Pechenga produced 86,500 mt of converter matte in 1994, containing 38,600 mt of Ni and 23,400 mt of Cu.

The Severonickel complex at Monchegorsk was processing converter matte from Norilsk and Pechenga, as well as ore from Norilsk. Up until 1977, Severonickel also used local ores as feed, but those reserves are now depleted. Severonickel recently began processing limited amounts of nickel-bearing concentrates, scrap, and residues shipped from abroad.

In November 1994, OMR and two Russian partners formed a joint venture to explore for nickel and other base metals on the Kola Peninsula.[41] The new venture, AOZT Kola Mining, also may help the regional government evaluate and develop several previously identified base metal sulfide deposits. The venture is headquartered in Monchegorsk, the principal townsite for Severonickel. Ownership of Kola Mining is shared between OMR (83%), the State Property Fund for the Murmansk Region (15%), and the Central Kola Expedition, a local geological exploration enterprise (2%).

In a related action, the Murmansk regional government solicited bids from Western companies to develop the Lovno Lake nickel sulfide deposit, about 40 km from the Finnish border. The deadline for bid submission was January 1, 1995. The award was to have been made by March 15. Kola Mining was a bidder and was planning to have a feasibility study completed by late 1996 if it won the competition. Officials of Kola Mining estimated that development of Lovno Lake would cost $150 million to $180 million. The Lovno ores are relatively low in nickel and copper (0.88% Ni and 0.43% Cu) compared with those at Norilsk, but contain above average concentrations of cobalt. Preliminary studies indicated that the Lovno deposit has about 8 to 10 million mt of ore, or roughly 12 years of reserves. The mine would initially be an open pit operation. Mining would move underground after 5 to 6 years to exploit the deeper ores.

OMR was also participating in a joint venture in neighboring Karelia. The venture, A/O Kivijärvi, was set up in 1992 to explore for copper and nickel and conduct mine feasibility studies of deposits in the Kivijärvi area, northeast of Aanisjärvi. This second venture is headquartered in Petrozavodsk and also operates from Segezha, on the Belomorsk Canal.[42]

***South Africa.***—The Columbus Stainless Steel Project was more than 97% complete and was scheduled to be commissioned in the fall of 1995. The huge stainless steelmaking complex had been under construction in the Transvaal since December 1992. When fully operational, the complex will be the largest single site producer of stainless and related chromium-bearing steels in the world.

The project is a joint venture of Samancor Ltd., Highveld Steel and Vanadium Ltd., and the Industrial Development Corp., each holding a one-third share. The project is costing the partnership 3.5 billion Rand *(roughly US$1 billion)*.

The new mill was being built around the existing Southern Cross stainless steel plant at Middelburg. Southern Cross Steel Co. (Pty.) Ltd. was the first company in South Africa to produce stainless steel, inaugurating operations at Middelburg in 1967. The company was acquired later by Middelburg Steel & Alloys (Pty.) Ltd., a wholly owned subsidiary of the Barlow Rand Group, only to be sold in July 1991 to the Columbus Joint Venture (i.e., the Columbus partnership).

The existing Southern Cross melt shop has a 50-mt electric arc furnace (EAF), a 60-mt argon-oxygen decarburization (AOD) furnace, and a single strand slab caster that together can produce up to 125,000 mt/a of crude stainless. This facility was being replaced by a totally new melt shop, which abuts the new combined hot rolling mill and cold rolling mill complex.

When the expansion is completed, the new melt shop will be able to produce 450,000 to

600,000 mt of continuous cast slab. Molten ferrochromium was being taken directly from Samancor's adjoining ferroalloy plant to the melt shop. There, the molten ferrochromium can be charged to either the EAF or the converter. The stainless steel was being refined using the Creusot-Loire-Uddeholm (CLU) process developed in the early 1970's. In the CLU process, superheated steam is used along with the oxygen as a refining agent.[43]

The production target for 1995 was 250,000 mt of stainless. Full production of 600,000 mt was scheduled to be reached in 1997. Products would include hot-rolled coil and band, cold-rolled band, cold-rolled plate of varying sizes, and slab.[44]

Impala Platinum Holdings Ltd. and Rustenburg Platinum Holdings Ltd. have been supplying most of the primary nickel consumed by the Columbus Joint Venture. South Africa produces about 30,000 mt/a of nickel as a byproduct of its platinum mines. However, by 1997, Columbus will require at least 48,000 mt/a of nickel. At that point, the joint venture plans to buy nickel on the world market. Only one-half of its nickel requirements would come from local sources. South Africa may have to import even more nickel if Iscor Ltd. proceeds with its plan to convert part of its Pretoria Works to stainless production.[45]

In September 1994, Gencor and the Royal Dutch/Shell Group finalized the terms on the sale of Billiton BV to Gencor. Gencor reportedly paid Shell $1.14 billion for the international mining, metals smelting, and trading company. Gencor is one of the larger mining houses in South Africa, with roots dating back to 1895. The long-awaited transfer of assets transformed Gencor into an international resource group. Gencor's new subsidiary is called Billiton International Ltd. The South African mining company had to put up $335 million in cash. The bulk of the remaining $809 million was loaned to Gencor by a consortium of international banks.

Gencor has become increasingly involved with nickel in recent years. The company is a majority stockholder in Samancor, giving it a direct interest in both South African ferroalloy production and the Columbus project. Gencor has a 42% interest in Impala Platinum which can produce roughly 12,000 mt/a of refined nickel as byproduct of its platinum operations in Bophuthatswana.

Gencor and the giant Anglo American Corp. of South Africa Ltd. have a number of mutual interests. Anglo American also is involved in the Columbus project through its holdings in Highveld. Like Gencor, Anglo American has sizable investments in South African companies that produce nickel as a byproduct of platinum mining. Another Anglo American subsidiary, Kaffrarian Metal Holdings (Pty.) Ltd., is a partner with Anglovaal Ltd. in the Nkomati (River of Cows) nickel-cobalt-copper exploration program.

Anglo American and Anglovaal have joined forces to explore a sill-like layered ultramafic complex in the eastern part of the Transvaal. To date, work has focused on the Slaaihoek farm and the adjoining Uitkomst farm where several zones of sulfide mineralization have been identified.[46]

***Tanzania.***—Additional nickel-copper-cobalt resources have been identified at Kabanga on the Burundi border. The Kabanga deposit was discovered by geologists with the United Nations Development Program in 1979 and acquired by Sutton Resources Ltd. in 1990. Since then, infill drilling by Sutton has confirmed the existence of a zone of moderately high nickel sulfide mineralization)the Main Zone. The Kabanga deposit is now being thoroughly evaluated as part of a joint venture between Sutton and BHP Minerals International Exploration Inc. (BHP Minerals). BHP Minerals has had drill rigs operating in the area since 1993.

In late 1993, stepout drilling intersected nickel sulfides about 1,100 m north of the Kabanga Main Zone. Subsequent infill drilling about 700 m north of the Main Zone has revealed a second, somewhat richer zone of nickel mineralization of unknown extent. According to Sutton consultants, this latest discovery - the North Zone - has at least 12.4 million mt of sulfide ore grading 2% Ni, 0.27% Cu, and 0.19% Co.[47] In comparison, the Main Zone has 23.1 million mt of ore averaging 1.19% Ni, 0.20% Cu, and 0.10% Co, based on a 0.5% Ni cutoff.

The Kabanga project is tied to a larger, ongoing exploration program that covers the entire Kagera region from Kabanga to the Uganda border. The region is bordered on the west by Rwanda and on the east by Lake Victoria. BHP is paying all of the exploration costs under an equity earning agreement reached with Sutton in June 1992. That same year, the Government of Tanzania awarded Sutton's Tanzanian subsidiary sole exploration rights in the Kagera Concession in exchange for a 10% position in the Kagera venture and a 3% royalty on any minerals produced. The Government also has a similar 10% position in the Kabanga venture.[48]

**Current Research and Technology**

Recent developments in Ni-Cd battery technology were reviewed at an international conference on September 19-20, 1994, in Geneva, Switzerland. The conference—*NiCad94*—was organized by the International Cadmium Association with the cooperation and support of Eurobat. Four of the 27 papers presented discussed large-scale field testing of EV's in Europe. Another eight dealt with the collection and recycling of spent batteries in both Europe and North America.

The Ni-Cd, nickel-metal hydride (Ni-MH), lithium-ion, and improved lead-acid electrochemical systems are in strong competition with one another for the portable rechargeable battery market. Improvements are continually being made to each of the systems. Energy density, cycle life, charge retention, shelf life, and performance at extreme temperatures are all being enhanced. These enhancements are being carried over into the emerging electric vehicle battery market)a market some analysts believe will be worth $300 million by the year 2000.

France, Germany, Japan, and the United States continue to be the principal manufacturers and users of Ni-Cd and Ni-MH batteries. However, tremendous strides have been made by competitors in China and Hong Kong since 1990. China now has nine Ni-Cd battery manufacturing operations. Another five Chinese suppliers produce Ni-Cd batteries as a sideline of their zinc-manganese dry cell operations. Seven of the fourteen Ni-Cd suppliers also manufacture Ni-MH batteries. An eighth, Innotec Environmental Energy Co. Ltd. in Tianjin, makes nothing but Ni-MH batteries.[49]

In France, the La Rochelle electric vehicle experiment is now in its sixth year of testing. The tests are a joint project of the city of La Rochelle, the automobile manufacturer PSA Peugeot Citroën, and the electric utility Electricité de France (EDF). Fifty EV's are currently operating in the city. Forty-six of the 50 EV's are powered by Ni-Cd systems; four by lead-acid.[50]

German automobile manufacturers have been conducting similar field tests in Zurich, Switzerland, and on the island of Rügen in the Baltic Sea. The 4-year project began in 1992 and is being run by Deutsche Automobilgesellschaft mbH (DAUG) with the support of the German Federal Ministry for Research and Technology. Of the 59 vehicles being tested, 23 have sealed Ni-Cd batteries developed by DAUG. Another 31 of the Rügen vehicles are being powered by sodium metal-nickel chloride ($Na^{o}$-$NiCl_2$) batteries made by AEG AG.[51]

The DAUG battery minimizes gas pressures within the cell by using split negative, cadmium electrodes. Because of the unique electrode design, oxygen evolution is automatically

controlled. The near-zero gas pressure allows the battery to be sealed and made maintenance-free. DAUG and Accumulatorenwerke HOPPECKE have formed a joint venture to manufacture the advanced Ni-Cd battery.

In the United States, commercial production of EV's powered by nickel batteries moved one step closer to reality. On May 13, 1994, the California Air Resources Board (ARB) reaffirmed its requirement that, beginning with the 1998 model year, 2% of all vehicles sold within the State must have zero tailpipe emissions. The regulation, adopted in 1990, requires all automobile manufacturers who sell more than 35,000 cars or light trucks annually in California after 1997 to certify that at least 2% of total sales were zero emission vehicles (ZEV's). The sales requirement jumps to 5% in the year 2001, and then to 10% in 2003. At the present time, only EV's can satisfy the zero emission requirement.[52]

Several auto manufacturers had hoped that the ARB would delay the deadline, giving the companies more time to improve the performance of their prototype EV's. The auto manufacturers were concerned about the limitations of existing battery technology (range, speed, manufacturing cost, and so forth) and the absence of a network of recharging stations. The Board, however, concerned about increasingly severe air quality problems in the Los Angeles basin, rejected the auto manufacturers' arguments. The Board then went on to adopt a detailed report prepared by its staff which concludes that zero-emission vehicles are "technologically feasible in the timeframe provided."[53]

The reaffirmation is important to nickel producers as well as battery manufacturers. During the near-term (1995-2000), at least four nickel-based EV batteries are expected to strongly compete with the new high-performance lead-acid battery being developed in Texas and other lead-based batteries of advanced design. The four nickel-based technologies are: nickel-cadmium, nickel-iron, nickel-metal hydride, and sodium metal-nickel chloride. In 1993, Chrysler Corp. demonstrated electric vehicle technology by driving a Ni-Cd powered, seven passenger minivan 2,500 miles from Detroit to Los Angeles in about 160 hours.

For several years now, the Ovonic Battery Co. has been developing an advanced Ni-MH battery for EV's. Part of this work is being funded by the U.S. Advanced Battery Consortium (USABC) under a long contract worth $19.9 million. The USABC recently awarded the Michigan company an additional $5.5 million to improve the performance of its existing Ni-MH EV battery while simultaneously lowering production costs.

In June 1994, General Motors Corp. (GM) entered into a joint venture with OBC to manufacture EV batteries utilizing proprietary Ni-MH technology. Details of the agreement were not disclosed. GM reportedly plans to begin pilot production of the Ovonic Ni-MH battery in 1996. The California Air Resources Board has been testing a number of EV's, including a four-seater Solectria powered by Ovonic Ni-MH batteries. Preliminary results indicate that the Solectria has a range of 275 km (170 miles) at approximately 80 km per hour (50 miles per hour).[54] Solectria Inc. turns motorless versions of the Geo Metro and other "gliders" into EV's at its plant in Wilmington, MA.

**Outlook**

Demand for austenitic stainless steel will continue to drive the world nickel market for at least another 20 years. World consumption of stainless steel is expected to grow between 3% and 9% annually from 1996 to the year 2000. This growth rate should increase substantially at some point when the Russian economy inevitably turns around and a rejuvenated Russian industry begins consuming the large amounts of stainless sheet and plate required by a technologically advanced, market-oriented society.

Demand for austenitic stainless has already resumed its upward growth in several OECD countries recovering from the global recession of 1991-93. Stainless production capacity is being expanded in some of the newly industrialized countries of the Far East that successfully weathered the recession. Brazil and South Africa both are poised to be major producers of stainless steel.

Many of the demand problems that hurt nickel producers in 1993 have receded. Western producers have largely adjusted to the massive Russian exports of cathode. Supplies of stainless scrap have tightened, and the nickel industry is again expanding mining and smelting capacity on a global basis. New technologies are being explored for improving the economics of recovering nickel from laterites.

The development of the Voisey Bay deposit should ease the fears of many consumers about future shortages of nickel. Recent drilling has delineated additional resources at depth in the immediate area of the discovery site and changed long-range thinking about future exploration targets elsewhere in the Northern Hemisphere. More than 100 companies currently are doing field work in the Voisey Bay region. Three of the more promising areas include Harp Lake, Niatak Island, and Tasisuak Lake.

Although still relatively small, demand for nickel in rechargeable batteries is growing at more than 10% per year. Manufacturing of Ni-Cd and Ni-MH batteries is expected to increase significantly over the next 5 years even if both chemistries are rejected for EV's. Nickel-based batteries will continue to be used in rechargeable power tools, home appliances, and other household equipment because of cost constraints. The markets for battery-powered cellular telephones, laptop computers, and other portable electronic equipment are exploding. Many of the newest satellites and commercial aircraft are using advanced Ni-Cd's for their secondary power sources.

A nationwide recycling system for nickel-based batteries is being set up in the United States that should lessen environmental concerns. INMETCO now has on-site facilities for refining the recovered cadmium and converting it into marketable stick. This was the last major technical impediment to unrestrained recycling of household and industrial Ni-Cd's.

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TABLE 1
SALIENT NICKEL STATISTICS 1/

(Metric tons of contained nickel unless otherwise specified)

| | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Mine production | 330 | 5,520 | 6,670 | 2,460 | -- |
| Plant production | 3,700 | 7,070 | 8,960 | 4,880 | -- |
| Secondary recovery from purchased scrap: | | | | | |
| From ferrous scrap | 48,600 | 44,800 | 47,700 | 46,600 r/ | 48,900 |
| From nonferrous scrap | 8,760 | 8,700 | 8,140 | 7,460 | 9,690 |
| Exports: | | | | | |
| Primary | 8,870 | 9,100 | 8,560 | 7,180 | 7,440 |
| Secondary | 28,200 | 27,800 | 25,300 | 26,000 | 34,500 |
| Imports for consumption: | | | | | |
| Ore | -- | 371 | 3,580 | 2,970 | -- |
| Primary | 134,000 | 132,000 | 119,000 | 126,000 | 127,000 |
| Secondary | 11,600 | 6,210 | 9,510 | 6,710 | 6,060 |
| Consumption: | | | | | |
| Reported: | | | | | |
| Primary | 121,000 | 109,000 | 101,000 | 105,000 r/ | 107,000 |
| Secondary (purchased scrap) | 57,400 | 53,500 | 55,900 | 54,000 r/ | 58,600 |
| Total | 178,000 | 162,000 | 157,000 | 159,000 r/ | 166,000 |
| Apparent: | | | | | |
| Primary | 127,000 | 125,000 | 119,000 | 122,000 r/ | 134,000 |
| Secondary (purchased scrap) | 42,800 | 31,400 | 40,300 | 36,600 r/ | 30,500 |
| Total | 170,000 | 157,000 | 159,000 | 158,000 r/ | 164,000 |
| Stocks, yearend: | | | | | |
| Government | 33,800 | 33,800 | 33,800 | 31,600 | 26,800 |
| Producer and traders | 8,070 | 11,800 | 10,100 | 15,700 r/ | 10,200 |
| Consumer: | | | | | |
| Primary | 9,060 | 10,500 r/ | 12,300 r/ | 11,100 r/ | 7,210 |
| Secondary | 4,920 | 5,440 | 5,180 | 3,330 r/ | 2,990 |
| Employment, yearend: | | | | | |
| Mine | 12 | 8 | 10 | 2 | 1 |
| Smelter | 300 | 277 | 250 | 33 | 22 |
| Port facility | -- | -- | 23 | 5 | 3 |
| Price, cash, London Metal Exchange: | | | | | |
| Per metric ton | $8,864 | $8,156 | $7,001 | $5,293 | $6,340 |
| Per pound | $4.021 | $3.699 | $3.176 | $2.401 | $2.876 |
| World: Mine production | 974,000 r/ | 991,000 r/ | 981,000 r/ | 905,000 r/ | 895,000 e/ |

e/ Estimated. r/ Revised.

1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits, except prices; may not add to totals shown.

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)

| | 1993 | 1994 |
|---|---|---|
| KIND OF SCRAP | | |
| Aluminum-base 2/ | 2,350 | 3,150 |
| Copper-base | 2,060 | 2,970 |
| Ferrous-base 3/ | 46,600 r/ | 48,900 |
| Nickel-base | 3,040 | 3,570 |
| Total | 54,000 r/ | 58,600 |
| FORM OF RECOVERY | | |
| Aluminum-base alloys 4/ | 2,350 | 3,150 |
| Copper-base alloys | 3,680 | 4,830 |
| Ferrous alloys | 46,600 r/ | 48,900 |
| Nickel-base alloys | 1,370 | 1,620 |
| Miscellaneous and unspecified | 2 | 41 |
| Total | 54,000 r/ | 58,600 |

r/ Revised.
1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.
2/ Primarily used beverage cans and foundry borings and turnings.
3/ Primarily stainless and alloy steel scrap consumed at steel mills and foundries.
4/ Includes can scrap converted to ingot by toll smelters for sale on open market.

TABLE 3
REPORTED U.S. CONSUMPTION OF NICKEL
BY FORM 1/

(Metric tons of contained nickel)

| Form | 1993 | 1994 |
|---|---|---|
| Primary: | | |
| Metal | 72,000 r/ | 80,100 |
| Ferronickel | 21,300 r/ | 18,900 |
| Oxide and oxide sinter 2/ | 4,440 | 3,690 |
| Chemicals | 1,800 r/ | 1,730 |
| Other | 5,700 | 3,000 |
| Total primary | 105,000 | 107,000 |
| Secondary (scrap) 3/ | 54,000 r/ | 58,600 |
| Grand total | 159,000 r/ | 166,000 |

r/ Revised.
1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.
2/ Included chemical-grade oxide.
3/ Based on gross weight of purchased scrap consumed and estimated average nickel content.

TABLE 4
U.S. CONSUMPTION OF NICKEL IN 1994, BY USE 1/

(Metric tons of contained nickel)

| Use | Metal | Ferro-nickel | Oxide and oxide sinter | Chemicals | Other forms | Total primary | Secondary (scrap) | 1994 grand total | 1993 grand total | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cast irons | 227 | W | (2/) | W | 47 | 274 | 225 | 499 | 805 | r/ |
| Chemicals and chemical uses | 1,250 | -- | W | 1,420 | W | 2,670 | -- | 2,670 | 1,170 | r/ |
| Electric, magnet, expansion alloys | W | W | -- | -- | -- | W | W | W | W | |
| Electroplating (sales to platers) | 15,500 | (2/) | W | W | 10 | 15,500 | W | 15,500 | 16,600 | r/ |
| Nickel-copper and copper-nickel alloys | 3,750 | W | W | W | W | 3,750 | 4,190 | 7,940 | 6,080 | |
| Other nickel and nickel alloys | 19,100 | W | W | -- | W | 19,100 | 1,430 | 20,500 | 17,000 | |
| Steel: | | | | | | | | | | |
| Stainless and heat-resistant | 18,500 | 17,600 | 2,720 | -- | 2,340 | 41,200 | 47,500 | 88,700 | 87,300 | r/ |
| Alloys (excludes stainless) | 4,790 | W | W | -- | (2/) | 4,790 | 1,140 | 5,930 | 4,940 | r/ |
| Superalloys | 11,700 | -- | (2/) | W | W | 11,700 | W | 11,700 | 10,800 | |
| Other 3/ | 5,160 | 1,290 | 973 | 303 | 595 | 8,320 | 4,070 | 12,400 | 14,500 | r/ |
| Total reported | 80,100 | 18,900 | 3,690 | 1,730 | 3,000 | 107,000 | 58,600 | 166,000 | 159,000 | r/ |
| Total all companies, apparent | XX | XX | XX | XX | XX | 134,000 | 30,500 | 164,000 | 158,000 | r/ |

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other." XX Not applicable.

1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.

2/ Less than 1/2 unit.

3/ Includes batteries, catalysts, ceramics, coinage, and other alloys containing nickel, and data represented by symbol "W."

TABLE 5
NICKEL IN CONSUMER STOCKS IN THE UNITED STATES,
BY FORM 1/

(Metric tons of contained nickel)

| Form | 1993 | | 1994 |
|---|---|---|---|
| Primary: | | | |
| Metal | 8,010 | r/ | 4,880 |
| Ferronickel | 1,710 | r/ | 553 |
| Oxide and oxide sinter | 915 | | 1,230 |
| Chemicals | 281 | r/ | 287 |
| Other | 158 | | 263 |
| Total primary | 11,100 | r/ | 7,210 |
| Secondary (scrap) | 3,330 | r/ | 2,990 |
| Grand total | 14,400 | r/ | 10,200 |

r/ Revised.

1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.

TABLE 6
U.S. EXPORTS OF NICKEL PRODUCTS , BY CLASS 1/

(Metric tons of contained nickel unless otherwise specified)

| Class | 1993 | | 1994 | |
|---|---|---|---|---|
| | Quantity | Value (thousands) | Quantity | Value (thousands) |
| Unwrought primary: | | | | |
| Cathodes, pellets, briquets, and shot | 755 | $4,130 | 564 | $4,040 |
| Ferronickel | 669 | 2,310 | 35 | 96 |
| Powder and flakes | 573 | 8,090 | 1,090 | 10,000 |
| Metallurgical-grade oxide 2/ | 3,750 | 6,550 | 3,640 | 7,370 |
| Chemicals: 3/ | | | | |
| Catalysts | 987 | 52,400 | 1,630 | 60,400 |
| Salts | 450 | 6,640 | 480 | 7,430 |
| Total | 7,180 | 80,100 | 7,440 | 89,300 |
| Unwrought secondary: 4/ | | | | |
| Stainless steel scrap | 17,900 | 147,000 | 22,400 | 190,000 |
| Waste and scrap | 8,170 | 31,700 | 12,100 | 45,200 |
| Total | 26,000 | 179,000 | 34,500 | 235,000 |
| Grand total | 33,200 | 259,000 | 41,900 | 325,000 |
| Wrought: | | | | |
| Bars, rods, profiles and wire | 237 | 2,010 | 257 | 3,280 |
| Sheets, strip and foil | 215 | 2,260 | 121 | 2,060 |
| Tubes and pipes | 99 | 1,490 | 49 | 573 |
| Total | 551 | 5,760 | 427 | 5,920 |
| Alloyed (gross weight): | | | | |
| Unwrought alloyed ingot | 1,890 | 18,600 | 2,830 | 21,000 |
| Bars, rods, profiles and wire | 4,540 | 63,600 | 4,290 | 59,600 |
| Sheets, strip and foil | 5,700 | 74,300 | 6,180 | 86,500 |
| Tubes and pipes | 1,060 | 24,900 | 1,160 | 22,300 |
| Other alloyed articles | 1,750 | 51,000 | 2,580 | 36,400 |
| Total | 14,900 | 232,000 | 17,000 | 226,000 |

1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.
2/ Chemical-grade oxide is included with the "Salts" category.
3/ For the different salts, the nickel contents are assumed to be as follows: chlorides, 25%; sulfates, 22%; other salts, 22%; and oxide, sesquoxide and hydroxide, 65%. The typical catalyst is assumed to have a nickel content of 22%.
4/ The nickel content of waste and scrap is assumed to be 50%, while that of stainless steel has been shown to be about 7.5%.

Sources: Bureau of the Census and Journal of Commerce.

TABLE 7
U.S. EXPORTS OF NICKEL PRODUCTS IN 1994, BY COUNTRY 1/

(Metric tons of contained nickel 2/)

| Country | Cathodes, pellets, and briquets, (unwrought) | Powder and flakes | Ferro-nickel | Metal-lurgical grade oxide 3/ | Waste and scrap | Stainless steel scrap | Chemicals | Totals 1994 | Totals 1993 | Wrought nickel 4/ |
|---|---|---|---|---|---|---|---|---|---|---|
| Australia | -- | 2 | -- | 104 | 78 | -- | 9 | 193 | 88 | 1 |
| Belgium | -- | 116 | -- | -- | 17 | 721 | 88 | 942 | 967 | 1 |
| Canada | 218 | 562 | 1 | 3,260 | 7,720 | 3,680 | 325 | 15,800 | 12,700 | 46 |
| China | -- | -- | -- | -- | 86 | 170 | 14 | 270 | 391 | 3 |
| Colombia | 9 | 2 | -- | 43 | -- | -- | 13 | 67 | 19 | 44 |
| Finland | -- | -- | -- | -- | 85 | -- | -- | 85 | 640 | (5/) |
| France | 46 | 7 | -- | -- | 62 | 20 | 34 | 169 | 188 | 71 |
| Germany | -- | 10 | -- | 20 | 551 | 69 | 50 | 700 | 493 | 1 |
| India | -- | (5/) | -- | -- | 28 | 357 | 2 | 387 | 394 | 1 |
| Italy | -- | (5/) | -- | (5/) | 22 | 1 | 2 | 25 | 40 | -- |
| Japan | -- | 36 | -- | 111 | 1,230 | 1,900 | 476 | 3,750 | 4,650 | 5 |
| Korea, South | 62 | 94 | -- | 3 | 112 | 5,760 | 124 | 6,150 | 5,310 | 17 |
| Mexico | 203 | 74 | 1 | (5/) | 11 | 27 | 186 | 502 | 526 | 56 |
| Netherlands | -- | 4 | -- | (5/) | 449 | 982 | 31 | 1,470 | 1,110 | 8 |
| Russia | -- | -- | -- | -- | 9 | -- | -- | 9 | 129 | -- |
| Spain | -- | (5/) | -- | 1 | 164 | 5,320 | 3 | 5,490 | 3,090 | -- |
| Sweden | -- | 2 | -- | (5/) | 971 | 1,680 | 1 | 2,650 | 220 | (5/) |
| Taiwan | -- | 6 | 33 | (5/) | 66 | 565 | 31 | 701 | 779 | 15 |
| United Kingdom | 1 | 45 | -- | 7 | 407 | 396 | 19 | 875 | 471 | 46 |
| Other | 25 | 126 | -- | 99 | 10 | 760 | 702 | 1,720 | 986 | 112 |
| Total | 564 | 1,090 | 35 | 3,640 | 12,100 | 22,400 | 2,110 | 41,900 | 33,200 | 427 |

1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to 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 chemical category contains the following: chemical-grade oxide, sesquoxide, and hydroxide, 65%; chlorides, 25%; and sulfates, 22%; other salts and various catalysts are assumed to be 22% nickel.
3/ Chemical-grade oxide is included with salts and catalysts in the chemicals category.
4/ Not included in "Total."
5/ Less than 1/2 unit.

Source: Bureau of the Census.

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

(Metric tons of contained nickel 2/ unless otherwise specified)

| Class | 1993 | | 1994 | |
|---|---|---|---|---|
| | Quantity | Value (thousands) | Quantity | Value (thousands) |
| Unwrought primary: | | | | |
| Cathodes, pellets, briquets, and shot | 95,900 | $516,000 | 95,700 | $552,000 |
| Ferronickel | 13,200 | 66,500 | 15,300 | 85,500 |
| Flakes | 212 | 1,320 | 275 | 2,020 |
| Powder | 8,490 | 73,700 | 8,800 | 78,400 |
| Metallurgical-grade oxide | 4,490 | 25,300 | 3,070 | 18,700 |
| Chemicals: | | | | |
| Catalysts | 2,490 | 41,900 | 2,330 | 36,700 |
| Salts | 1,540 | 15,000 | 1,620 | 16,700 |
| Total | 126,000 | 739,000 | 127,000 | 790,000 |
| Unwrought secondary: | | | | |
| Stainless steel scrap | 3,700 | 20,200 | 3,190 | 20,200 |
| Waste and scrap | 3,020 | 19,100 | 2,880 | 21,700 |
| Total | 6,710 | 39,300 | 6,060 | 41,900 |
| Grand total | 133,000 | 779,000 | 133,000 | 832,000 |
| Wrought: | | | | |
| Bars, rods, profiles and wire | 449 | 4,920 | 238 | 3,100 |
| Sheets, strip and foil | 490 | 9,480 | 352 | 4,440 |
| Tubes and pipes | 52 | 1,040 | 45 | 1,200 |
| Total | 991 | 15,400 | 634 | 8,740 |
| Alloyed (gross weight): | | | | |
| Unwrought alloyed ingot | 2,720 | 19,500 | 2,720 | 20,300 |
| Bars, rods, profiles and wire | 2,170 | 24,200 | 2,470 | 28,000 |
| Sheets, strip and foil | 1,280 | 16,000 | 1,310 | 15,300 |
| Tubes and pipes | 570 | 15,600 | 801 | 19,900 |
| Other alloyed articles | 306 | 5,450 | 380 | 10,200 |
| Total | 7,050 | 80,800 | 7,680 | 93,800 |

1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.

2/ The nickel contents are as follows: metallurigical-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.

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

(Metric tons of contained nickel 2/)

| Country | Cathodes, pellets, and briquets, (unwrought) | Powder and flakes | Ferro-nickel | Metal-lurgical grade oxide 3/ | Waste and scrap | Stainless steel scrap | Chemicals | Totals 1994 | Totals 1993 | Wrought nickel 4/ |
|---|---|---|---|---|---|---|---|---|---|---|
| Australia | 13,400 | 1,170 | -- | 2,730 | 18 | -- | -- | 17,300 | 13,600 | -- |
| Austria | -- | 40 | 119 | -- | -- | -- | (5/) | 159 | 381 | (5/) |
| Belgium | -- | -- | -- | -- | 7 | -- | 282 | 289 | 600 | (5/) |
| Brazil | 4,760 | -- | 380 | -- | -- | -- | 4 | 5,150 | 2,240 | -- |
| Canada | 38,000 | 6,700 | --- | 336 | 1,000 | 1,770 | 1,810 | 49,600 | 62,300 | 53 |
| Colombia | -- | -- | 2,120 | -- | 4 | 10 | -- | 2,130 | 1,210 | -- |
| Dominican Republic | -- | -- | 8,140 | -- | 27 | -- | -- | 8,170 | 6,280 | -- |
| Finland | 2,090 | -- | -- | -- | -- | -- | 423 | 2,520 | 2,450 | -- |
| France | 1,100 | (5/) | -- | -- | 479 | --- | 192 | 1,770 | 2,010 | 47 |
| Germany | 20 | 9 | -- | -- | 293 | --- | 253 | 575 | 503 | 453 |
| Japan | 1 | 3 | 5 | (5/) | 69 | 16 | 560 | 654 | 740 | 15 |
| Macedonia | -- | -- | -- | -- | -- | -- | -- | -- | 295 | -- |
| Mexico | -- | -- | -- | -- | 33 | 1,060 | (5/) | 1,090 | 1,460 | -- |
| New Caledonia | -- | -- | 3,760 | -- | -- | -- | -- | 3,760 | 4,080 | -- |
| Norway | 22,300 | 2 | -- | -- | 17 | --- | --- | 22,300 | 18,500 | -- |
| Russia | 4,660 | 640 | 790 | --- | 15 | 2 | 27 | 6,130 | 6,720 | -- |
| South Africa, Republic of | 4,830 | 352 | 25 | --- | 3 | --- | 48 | 5,260 | 5,580 | -- |
| United Kingdom | 880 | 107 | 4 | --- | 659 | --- | 51 | 1,700 | 823 | 10 |
| Zimbabwe | 2,640 | -- | -- | -- | -- | -- | -- | 2,640 | 1,950 | -- |
| Other | 1,010 | 47 | 9 | --- | 248 | 329 | 295 | 1,950 | 1,360 | 56 |
| Total | 95,700 | 9,070 | 15,300 | 3,070 | 2,880 | 3,190 | 3,940 | 133,000 | 133,000 | 634 |

1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.
2/ The nickel content of metallurgical-grade oxide from Australia is assumed to be 90%; elsewhere 77%. The chemicals category contains the following: chemical-grade oxide, sequoxide, 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%.
3/ Primarily oxide rondelles and sinter.
4/ Not included in "Total."
5/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 10
NICKEL: WORLD MINE PRODUCTION, BY COUNTRY 1/

(Metric tons of contained nickel 2/)

| Country | 1990 | 1991 | 1992 | 1993 | 1994 e/ |
|---|---|---|---|---|---|
| Albania (content of ore) e/ | 8800 | 7500 | 150 | 75 | -- |
| Australia (content of concentrate) | 67,000 | 69,000 | 57,700 | 64,700 | 71,900 |
| Botswana (content of ore milled) | 23,200 | 23,500 | 23,000 | 23,000 | 23,000 |
| Brazil (content of ore) | 24,100 r/ | 26,400 r/ | 29,400 r/ | 32,200 r/ | 32,000 |
| Burma (content of ore) | 42 r/ | 15 r/ | 9 r/ | 67 r/ | 50 |
| Canada (content of concentrate) | 196,000 | 192,000 | 186,000 | 188,000 | 150,000 3/ |
| China e/ | 33,000 | 30,400 | 32,800 | 30,700 r/ | 33,000 |
| Colombia (content of laterite ore) | 22,400 | 20,600 | 23,100 | 23,300 | 23,500 |
| Cuba (content of oxide, sinter, sulfide) | 40,800 | 33,300 | 32,200 | 30,200 | 26,000 |
| Dominican Republic (content of ferronickel produced) | 28,700 | 29,100 | 27,500 | 23,900 | 30,500 |
| Finland (content of concentrate) | 11,500 | 9,900 | 9,870 | 8,290 r/ | 7,250 3/ |
| Germany | 872 | XX | XX | XX | XX |
| Greece (laterite ore) | 18,500 | 19,300 | 17,000 r/ | 12,900 r/ | 19,000 |
| Indonesia (content of ore) | 68,300 | 71,700 | 77,600 | 65,800 e/ | 81,100 3/ |
| New Caledonia (content of ore) | 85,100 | 114,000 | 113,000 | 97,100 r/ | 96,000 3/ |
| Norway (content of concentrate) | 3,100 | 2,200 | 3,400 | 3,460 | 3,320 3/ |
| Philippines | 15,800 | 13,700 | 13,000 r/ | 7,660 r/ | 9,800 |
| Russia e/ | XX | XX | 280,000 | 243,000 r/ | 240,000 |
| Serbia and Montenegro (content of ferronickel produced) 4/ | XX | XX | 1,860 r/ | 443 r/ | 450 |
| South Africa, Republic of (content of concentrate) | 29,000 | 27,700 | 28,400 | 30,000 r/ e/ | 31,000 |
| Ukraine e/ | XX | XX | 5,900 r/ | 4,500 | 4,000 |
| U. S. S. R. (content of ore) e/ 5/ | 280,000 | 280,000 | XX | XX | XX |
| United States (content of ore shipped) | 330 | 5,520 | 6,670 | 2,460 3/ | |
| Yugoslavia ( content of ferronickel produced) e/ 4/ 6/ | 3,600 | 2,400 | XX | XX | XX |
| Zimbabwe (content of concentrate) | 13,500 | 12,400 | 12,400 | 12,800 r/ | 13,500 3/ |
| Total | 974,000 r/ | 991,000 r/ | 981,000 r/ | 905,000 r/ | 895,000 |

e/ Estimated. r/ Revised. XX Not applicable.

1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits, except prices; may not add to totals shown.

2/ Insofar as possible, this tabel 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 or by a footnote following the country name. Finland and the United States both reported receiving ferronickel originating from Macedonia in 1992, but definitive information on the output of the Kavadarci operation was not available. Tables includes data available through July 27, 1995.

3/ Reported figure.

4/ All production in Yugoslavia for 1990-91 came from Serbia and Montenegro.

5/ Dissolved in Dec. 1991.

6/ Dissolved in Apr. 1992.

TABLE 11
NICKEL: WORLD PLANT PRODUCTION BY COUNTRY AND PRODUCT 1/ 2/

(Metric tons of nickel content)

| Country 3/ and product | 1990 | 1991 | 1992 | 1993 | 1994 e/ |
|---|---|---|---|---|---|
| Albania: Metal e/ | 2,500 | 2,200 | 50 | 50 | 50 |
| Australia: Unspecified | 43,100 r/ | 49,400 r/ | 50,600 r/ | 50,400 r/ | 45,900 4/ |
| Austria: Ferronickel | 3,300 | 3,500 | 3,900 r/ | 3,200 r/ | 2,100 |
| Brazil: 5/ | | | | | |
| Ferronickel | 8,850 | 8,620 | 8,740 r/ | 8,680 r/ | 8,700 |
| Metal | 4,160 | 5,220 | 5,930 | 7,020 r/ | 7,000 |
| Total | 13,000 | 13,800 | 14,700 r/ | 15,700 r/ | 15,700 |
| Canada: Unspecified 6/ | 135,000 | 132,000 | 135,000 | 123,000 | 105,000 4/ |
| China: Metal e/ | 27,500 | 28,900 | 30,800 | 30,500 r/ | 31,000 |
| Colombia: Ferronickel | 18,400 | 20,200 | 20,200 | 18,000 r/ | 20,800 4/ |
| Cuba: Oxide 7/ | 21,100 | 18,800 | 16,900 | 16,200 r/ | 14,100 4/ |
| Czechoslovakia: Metal 8/ 9/ | 2,970 e/ | 2,400 e/ | 1,620 | XX | XX |
| Dominican Republic: Ferronickel | 28,700 | 29,100 | 27,500 | 23,900 | 30,500 |
| Finland: | | | | | |
| Chemicals | 1,640 | 2,160 | 2,890 | 3,130 | 4,190 |
| Metal | 16,900 | 13,900 | 14,800 | 14,800 | 15,900 |
| Total | 18,500 | 16,000 | 17,700 | 17,900 | 20,100 |
| France: | | | | | |
| Chemicals | 1,090 | 1,000 | 1,200 e/ | 1,200 e/ | 1,200 |
| Metal | 8,540 | 7,400 | 6,800 e/ | 10,400 r/ | 10,000 |
| Total | 9,630 | 8,400 | 8,000 e/ | 11,600 r/ e/ | 11,200 |
| Germany: Eastern states: Metal | 1,660 | 850 | XX | XX | XX |
| Greece: Ferronickel | 15,700 | 16,000 | 15,400 | 10,900 r/ | 16,200 4/ |
| Indonesia: Ferronickel | 5,010 | 5,320 | 5,510 | 5,270 | 5,800 4/ |
| Japan: | | | | | |
| Ferronickel | 56,500 | 68,000 | 57,400 | 51,100 r/ | 58,200 |
| Metal | 22,300 | 23,700 | 22,000 | 22,600 r/ | 25,300 4/ |
| Oxide | 21,500 | 22,500 | 27,500 | 27,000 r/ | 27,000 |
| Total | 100,000 | 114,000 | 107,000 | 101,000 r/ | 111,000 |
| Korea, Republic of: Metal e/ | 5,990 4/ | 11,300 | 10,000 | 10,000 | 10,000 |
| New Caledonia: Ferronickel | 32,300 | 34,400 | 31,900 | 36,900 | 39,500 4/ |
| Norway: Metal | 57,800 | 58,700 | 55,700 | 56,800 | 68,000 4/ |
| Russia: e/ 10/ | | | | | |
| Ferronickel | XX | XX | 22,000 | 17,000 | 15,000 |
| Metal | XX | XX | 205,000 | 160,000 | 155,000 |
| Oxide | XX | XX | 13,000 | 10,000 | 8,000 |
| Chemicals | XX | XX | 3,000 | 2,000 | 2,000 |
| Total | XX | XX | 243,000 | 189,000 | 180,000 |
| Serbia and Montenegro: Ferronickel | XX | XX | 1,860 r/ | 443 r/ | 450 |
| South Africa, Republic of: Metal | 28,200 | 26,900 | 27,600 | 29,900 r/ | 30,100 4/ |
| Sweden: Metal | 610 | 490 | 500 e/ | 500 e/ | 500 |
| Taiwan: Metal e/ | 10,400 | 11,200 | 10,000 | 9,000 | 10,000 |
| Ukraine: Ferronickel e/ | XX | XX | 5,000 r/ | 3,500 | 3,000 |
| U.S.S.R.: e/ 10/ 11/ | | | | | |
| Ferronickel | 22,000 | 20,000 | XX | XX | XX |
| Metal | 240,000 | 230,000 | XX | XX | XX |
| Oxide | 13,000 | 12,000 | XX | XX | XX |
| Total | 275,000 | 262,000 | XX | XX | XX |
| United Kingdom: Metal | 26,800 | 29,000 | 28,000 e/ | 28,000 e/ | 28,000 |
| United States: Ferronickel | 3,700 | 7,070 | 8,960 | 4,880 | -- 4/ |
| Yugoslavia: Ferronickel e/ | 3,600 | 2,500 | XX | XX | XX |
| Zimbabwe: Metal 12/ | 11,400 | 11,300 | 10,300 | 11,100 | 11,500 |
| Total chemicals | 2,730 | 3,160 | 7,090 | 6,330 | 7,390 |
| Total ferronickel | 198,000 | 215,000 | 208,000 r/ | 184,000 r/ | 200,000 |
| Total metal | 468,000 | 463,000 | 429,000 | 391,000 r/ | 402,000 |
| Total oxide | 55,600 | 53,300 | 57,400 | 53,200 r/ | 49,100 |
| Total unspecified | 178,000 | 181,000 r/ | 186,000 r/ | 174,000 r/ | 151,000 |
| Grand total | 902,000 | 915,000 r/ | 888,000 r/ | 808,000 r/ | 810,000 |

e/ Estimated. r/ Revised. XX Not applicable.

1/ Table includes data available through July 27, 1995.

2/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.

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. Between 1992 and 1994, five members of the European Union, the Republic of South Korea, and the United States reported recieving ferronickel originating from Macedonia, but definitive information on the output of the Kavadarci operation was not available. Several countries produce nickel-containing matte, but output of nickel in such materials has been excluded from this table in order to avoid double counting. Countries producing matte include the following, with output indicated in metric tons of contained nickel: Australia (estimated): 1990-94--45,000; Botswana: 1990--19,000; 1991--19,300; 1992--18,900; 1993--21,600; and 1994--20,600 (estimated); Canada (estimated): 1990--43,300; 1991-94--40,000; Indonesia: 1990--24,900; 1991--27,400; 1992-- 39,300; 1993--37,000 (revised); and 1994--37,000; New Caledonia: 1990--9,680; 1991--9,040; 1992--7,480; 1993--10,900; and 1994--10,600.

4/ Reported figure.

5/ Brazil is believed to also produce nickel oxide, but information is not available on which to base estimates.

6/ Nickel contained in products of smelters and refineries in forms which are ready for use by consumers.

7/ Cuba also produces nickel sulfide but, because it is used as feed material elsewhere, it is not included to avoid double counting. Output of processed sulfide was as follows, in metric tons: 1990--19,700; 1991--14,600; 1992--15,300; 1993--14,000; and 1994--12,800.

8/ Dissolved Dec. 31, 1992.

9/ All production in Czechoslovakia from 1990-92 came from Slovakia. Production for 1993 is estimated to be zero.

10/ Includes production from sulfidized concentrates shipped from Cuba for toll refining.

11/ Dissolved in Dec. 1991.

12/ Excludes production from matte shipped from Botswana for toll refining.