COLUMBIUM (NIOBIUM) AND TANTALUM

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Columbium (niobium) is vital as an alloying element in steels and in superalloys for aircraft turbine engines and is in greatest demand in industrialized countries. It is critical to the United States because of its defense-related uses in the aerospace, energy, and transportation industries. Substitutes are available for some columbium applications, but, in most cases, they are less desirable.

Tantalum is a refractory metal that is ductile, easily fabricated, highly resistant to corrosion by acids, a good conductor of heat and electricity, and has a high melting point. It is critical to the United States because of its defense-related applications in aircraft, missiles, and radio communications. Substitution for tantalum is made at either a performance or economic penalty in most applications.

Neither columbium nor tantalum was mined domestically because U.S. resources are of low grade. Some resources are mineralogically complex, and most are not currently recoverable. The last significant mining of columbium and tantalum in the United States was during the Korean conflict, when increased military demand resulted in columbium and tantalum ore shortages.

Pyrochlore was the principal columbium mineral mined worldwide. Brazil and Canada, which were the dominant pyrochlore producers, accounted for most of the total estimated columbium mine production in 2003. The two countries, however, no longer export pyrochlore—only columbium in upgraded valued-added forms produced from pyrochlore. Brazil exported mostly regular-grade ferrocolumbium and columbium oxide, and Canada exported regular-grade ferrocolumbium. The remaining columbium mineral supply came mostly from the mining of columbite-tantalite in Australia, Nigeria, and certain other African countries. Tantalum mineral was produced mostly from tantalite-columbite mining operations in Australia, which was more than 60% of the total estimated tantalum mine production in 2003, and from other tantalum mine operations in Brazil, Canada, and certain African countries. The United States remained dependent on imports of columbium and tantalum materials; Brazil was the major source for columbium, and Australia, the major source for tantalum. The Defense National Stockpile Center (DNSC) offered and sold selected columbium and tantalum materials from the National Defense Stockpile (NDS). Columbium price quotations remained stable, and overall price quotations for tantalite ore decreased. Overall reported consumption of columbium in the form of ferrocolumbium and nickel columbium increased. Tantalum consumption was unchanged.

Legislation and Government Programs

Summaries of important columbium and tantalum statistics are listed in tables 1 and 2, respectively. To ensure supplies of columbium and tantalum during an emergency, various materials have been purchased for the NDS (table 3). The NDS had no goals for columbium and tantalum materials effective as of December 28, 2001. For fiscal year (FY) 2003 (October 1, 2002, through September 30, 2003), the DNSC disposed of about 182 metric tons (t) of columbium contained in columbium concentrates (no columbium value was obtained, as the columbium was contained within tantalum minerals). There were no sales of columbium metal ingots in FY 2003. The DNSC's columbium carbide inventory was exhausted in FY 2002, and its ferrocolumbium inventory was exhausted in FY 2001. The DNSC also sold about 1 t of tantalum contained in tantalum capacitor-grade metal valued at about $107,000, about 18 t of tantalum contained in tantalum metal ingots valued at about $2.17 million, and about 199 t of tantalum contained in tantalum minerals valued at about $10 million. There were no sales of tantalum carbide powder and tantalum oxide in FY 2003. As of September 30, 2003, tantalum inventory sold but not shipped from the NDS included about 175 t of tantalum contained in tantalum minerals (U.S. Department of Defense, 2004, p. 11-13, 51, 53-54, 56).

In its revised Annual Materials Plan (AMP) for FY 2004 (October 1, 2003, through September 30, 2004) and proposed AMP for FY 2005 (October 1, 2004, through September 30, 2005), the DNSC had authority to sell the following columbium and tantalum materials (actual quantity limited to remaining sales authority or inventory, with the exception of columbium concentrates): about 254 t of columbium contained in columbium concentrates, about 9 t of columbium contained in columbium metal ingots, about 2 t of tantalum contained in tantalum carbide powder, about 18 t of tantalum contained in tantalum metal ingots, about 18 t of tantalum contained in tantalum metal powder, about 227 t of tantalum contained in tantalum minerals, and about 9 t of tantalum contained in tantalum oxide (Defense National Stockpile Center, 2004a, b). For FY 2004, through June 30, 2004, the DNSC disposed of about 44 t of columbium contained in columbium concentrates (no columbium value was obtained, as the columbium was contained within tantalum minerals), about 9 t of columbium contained in columbium metal ingots valued at about $304,000, about 17 t of tantalum contained in tantalum capacitor-grade metal powder valued at about $1.69 million, about 18 t of tantalum contained in tantalum metal ingots valued at about $2.06 million, about 161 t of tantalum contained in tantalum minerals valued at about $12.2 million, and about 9 t of tantalum contained in tantalum oxide valued at about $532,000.

On June 3, 2004, the DNSC announced that sales of stockpiled columbium and tantalum materials were suspended following a review of the statutory revenue ceilings for the materials. DNSC sales of columbium, diamond stone, tantalum, and tungsten materials are subject to a statutory revenue ceiling of $770 million. Sales of these materials must cease once the ceiling is reached and would not resume until further legislative authority is granted (American Metal Market, 2004; Defense National Stockpile Center, 2004c; Ryan's Notes, 2004).

Production

Neither columbium nor tantalum was mined domestically in 2003. Domestic production data for ferrocolumbium are developed by the U.S. Geological Survey (USGS) from the annual voluntary domestic survey for ferroalloys. Ferrocolumbium production data for 2003 were, however, incomplete at the time this report was prepared.

Cabot Supermetals (formerly Cabot Performance Materials, a business unit of Cabot Corporation, Boston, MA), Boyertown, PA, had production capability that ranged from raw material processing through the production of columbium and tantalum end products. H.C. Starck Inc., Newton, MA, was a major supplier of tantalum and columbium products. Reading Alloys Inc., Robesonia, PA, and Wah Chang, Albany, OR, were major producers of high-purity columbium products. Kennametal Inc., Latrobe, PA, was a major supplier of columbium and tantalum carbides (table 9).

In August, Cabot Supermetals announced plans to invest about $12 million to build a 90,000-square-foot thin films facility to be located east of Columbus, OH, in the Etna Corporate Park. The facility was expected to be fully operational in 2004 and would employ more than 50 people at the site. The new facility was intended for the manufacture of high-performance tantalum materials for use in flat panel display thin films, magnetics, optics, and semiconductor applications. According to the company, "This investment demonstrates our commitment to developing new products that address the future demands of our customers as they grow. The new facility will bring increased value to our customers and shareholders and strengthen our reputation for world-class technology" (Cabot Corporation, 2003, p. 4-5; 2003§[1]).

In July, KEMET Corp. of Greenville, SC, a major tantalum capacitor manufacturer, announced its strategic plan for enhancing the company's position as a global leader in passive electronic technologies. During the next 2 years, several key company facilities would be relocated based on access to key customers, availability of low cost resources, and technical resources. Corporate headquarters would remain in Greenville, but some evolving individual functions might be moved in order to support global activities in Asia, Europe, and North America. Some commodity manufacturing would be relocated to the company's lower cost manufacturing facilities in China and Mexico from the United States, with approximately 650 production-related jobs in the United States being affected during the next 2 years. The remaining U.S. production would focus primarily on early stage manufacture of new and other specialty products, with customers predominantly located in North America. Manufacturing facilities in Victoria, British Columbia, Canada, and Matamoros, Mexico, would focus primarily on tantalum and polymer capacitors and would be the company's primary production facilities supporting North American and European customers (KEMET Corp., 2003a§).

In February 2004, KEMET, announced the grand opening of its new capacitor facility in Suzhou (near Shanghai), China, which began production in October 2003. A second production facility in China is expected to be operational in 2004. According to the company, "A quarter of our current revenue is generated in Asia, and a long-term trend of many [of] our European and North American based customers is migrating manufacturing operations to Asia, in particular China." In November, KEMET's Asian headquarters was relocated from Singapore to Shanghai, China. "This move reflects the rapid growth in KEMET's customer base in Asia, and the increasing emphasis on establishing a strong local presence in this region" (KEMET Corp., 2003b§, c§, 2004§).

Consumption

Overall U.S. reported consumption of columbium as ferrocolumbium and nickel columbium increased by about 16% compared with that of 2002. Consumption of columbium by the steelmaking industry also increased by about 16%, with consumption up in all major reported steel end-use categories. Demand for columbium in superalloys increased to about 933 t from about 813 t (table 4). That portion used in the form of nickel columbium increased to about 473 t from about 365 t. Overall U.S. apparent consumption of all columbium materials was estimated to be about 4,300 t, compared with about 4,100 t in 2002.

In 2003, estimated overall U.S. apparent consumption of all tantalum materials was about 500 t, about the same as in 2002. Tantalum was consumed mostly in the form of alloys, compounds, fabricated forms, ingot, and metal powder. More than 60% of total tantalum consumed was in the electronics industry, mainly in the form of tantalum capacitors. Major end uses for tantalum capacitors included automotive electronics, pagers, personal computers, and portable telephones.

Columbium.—Columbium and niobium are synonymous names for the chemical element with atomic number 41; columbium was the name given in 1801, and niobium was the name officially designated by the International Union of Pure and Applied Chemistry in 1950. The metal conducts heat and electricity well, has a high melting point (about 2,470° C), is readily fabricated, and is highly resistant to many chemical environments.

Columbium in the form of ferrocolumbium is used worldwide, mostly as an alloying element in steels and in superalloys. Because of its refractory nature, appreciable amounts of columbium in the form of high-purity ferrocolumbium and nickel columbium are used in cobalt-, iron-, and nickel-base superalloys for such applications as heat-resisting and combustion equipment, jet engine components, and rocket subassemblies. Columbium carbide is used in cemented carbides to modify the properties of the cobalt-bonded tungsten

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

carbide-based material to impart toughness and shock resistance. It is usually used along with carbides of other metals, such as tantalum and titanium. Columbium oxide is the intermediate product used in the manufacture of columbium carbide, columbium metal, high-purity ferrocolumbium, and nickel columbium. Acceptable substitutes, such as molybdenum, tantalum, titanium, tungsten, and vanadium, are available for some columbium applications, but substitution may lower performance and/or cost effectiveness.

Columbium was recycled mostly from products of columbium-bearing steels and superalloys; little was recovered from products specifically for their columbium content. Detailed data on the quantities of columbium recycled in 2003 are not available but may compose as much as 20% of U.S. apparent consumption (Cunningham, 2004a).

Tantalum.—The major use for tantalum as tantalum metal powder is in the production of electronic components, mainly tantalum capacitors. The tantalum capacitor exhibits reliable performance and combines compactness and high efficiency with good shelf life. Applications for tantalum capacitors include communication systems, computers, and instruments and controls for aircraft, missiles, ships, and weapon systems. Because of its high melting point (about 3,000° C), good strength at elevated temperatures, and good corrosion resistance, tantalum is combined with cobalt, iron, and nickel to produce superalloys that are used in aerospace structures and jet engine components. Tantalum carbide, which is used mostly in mixtures with carbides of such metals as columbium, titanium, and tungsten, is used in boring tools, cemented-carbide cutting tools, farm tools, and wear-resistant parts. Owing to tantalum's excellent corrosion-resistant properties, tantalum mill and fabricated products are used for corrosion and heat-resistant chemical plant equipment, such as condensers, evaporators, heat exchangers, heating elements, and liners for pumps and reactors. Substitutes, such as aluminum, rhenium, titanium, tungsten, and zirconium, can be used in place of tantalum but are usually used at either a performance or economic penalty.

Tantalum was recycled mostly from new scrap that was generated during the manufacture of tantalum-related electronic components and new and old scrap products of tantalum-containing cemented carbides and superalloys. Detailed data on the quantities of tantalum recycled in 2003 are not available but may compose as much as 20% of U.S. apparent consumption (Cunningham, 2004b).

Prices

Published prices for pyrochlore concentrates produced in Brazil and Canada were not available because these concentrates were consumed internally by producers of regular-grade ferrocolumbium in Brazil and Canada and are no longer being exported. A price for Brazilian pyrochlore has not been available since 1981, and the published price for pyrochlore produced in Canada was discontinued in early 1989. The columbium price is affected most by the availability of regular-grade ferrocolumbium produced from pyrochlore. The yearend 2003, American Metal Market published price for regular-grade ferrocolumbium was at a range of $6.45 to $6.70 per pound of contained columbium compared with a range of $6.50 to $6.70 per pound at yearend 2002. The Metal Bulletin price for columbite ore, based on a minimum 65% contained columbium oxide (Nb_2O_5) and tantalum oxide (Ta_2O_5), was discontinued in October 2001 at a range of $5.50 to $7 per pound. The American Metal Market published price for high-purity (vacuum-grade) ferrocolumbium was discontinued in February-March 2002 at a range of $17.50 to $18 per pound of contained columbium. According to one industry analyst, "Prices for niobium oxide, other niobium chemicals, niobium metal and various alloys derived from either pyrochlore or other niobium-bearing sources are highly variable and depend on product specifications, volume, and processing considerations" (Mosheim, 2003a, p. 5).

Significant events affecting columbium prices since 1958 include the following: 1960-70, development of pyrochlore deposits in Brazil and Canada; 1970-79, increased demand and consequent rising prices; 1980, columbium oxide produced from pyrochlore-based feed material; 1981, exports of Brazilian pyrochlore ceased; 1994, production of ferrocolumbium began in Canada; 1997-98, sales of ferrocolumbium from the NDS; and 1998, expansion of ferrocolumbium production capacity in Brazil (Cunningham, 1999a).

The price for tantalum products is affected most by events in the supply of and demand for tantalum minerals. Yearend 2003 published prices for tantalite ore (per pound of contained oxide) were as follows: Platts Metals Week, a range of $30 to $40 compared with a range of $40 to $50 at yearend 2002; Metal Bulletin, a range of $20 to $30, unchanged since August 2002; and Ryan's Notes, a range of $20 to $25, unchanged since August 2002. The Metal Bulletin published price for Greenbushes tantalite ore, Australia, was $40 per pound contained oxide, unchanged since April 1991. According to one industry analyst, "The pricing of tantalum chemicals, metal powders, alloys, and fabricated articles is generally established by negotiation between buyer and seller. Specifications for a particular chemical, metal powder, or fabricated article of metal or tantalum alloy are dictated by the application. Specifications, their influence on processing requirements, and the volume of a specific product, all influence the prices negotiated between buyer and seller" (Mosheim, 2003b, p. 6).

Significant events affecting tantalum prices since 1958 include the following: 1979-80, tantalum price accelerates to record levels, owing in part to overoptimistic forecasts of market growth; 1982, industry's accumulation of large tantalum material inventories; 1988, drawdown of tantalum material inventories by processors; 1990, purchase of tantalum materials for the NDS; 1991, long-term tantalum supply contracts between major producer and processors; 1998, sales of tantalum minerals from the NDS (Cunningham, 1999b); and 2000, overoptimistic forecasts of market growth and an apparent shortage of tantalum source materials for processing.

Foreign Trade

Table 5 lists columbium and tantalum export and import data. For exports, overall trade value and total gross weight increased. In descending order, the United Kingdom, Israel, Germany, Japan, Taiwan, and France were the major recipients of the columbium and tantalum materials, on the basis of value, with more than 90% of the total. For imports, overall trade value and total gross weight decreased. In descending order, Brazil, Australia, Japan, Germany, Canada, and China were the major sources of columbium and tantalum imports, on the basis of value, with about 86% of the total.

Imports for consumption of columbium ores and concentrates increased (table 6). Imports at an average grade of approximately 30% Nb_2O_5 and 32% Ta_2O_5 were estimated to contain about 5 t of columbium and about 6 t of tantalum. Ferrocolumbium imports were up slightly, with Brazil accounting for about 86% of the total. Brazil accounted for about 70% of the total value of columbium imports.

Imports for consumption of tantalum ores and concentrates were down significantly (table 7); imports from Australia accounted for more than 80% of quantity and more than 90% of value. Imports at an average grade of approximately 37% Ta_2O_5 and 16% Nb_2O_5 were estimated to contain about 474 t of tantalum and about 175 t of columbium.

The schedule of tariffs applied during 2003 to U.S. imports of selected columbium and tantalum materials is found in the Harmonized Tariff Schedule of the United States—2003 (U.S. International Trade Commission, 2002). Brazil, which was the major source for columbium imports into the United States, accounted for about 76% of the total, in units of contained columbium, and Australia, which was the major source for tantalum imports into the United States, accounted for about 56% of the total, in units of contained tantalum (figures 1, 2).

Net import reliance as a percentage of apparent consumption is used to measure the adequacy of current domestic columbium and tantalum production to meet U.S. demand. For columbium in 2003, net import reliance as a percentage of apparent consumption was 100%. For tantalum, net import reliance as a percentage of apparent consumption was estimated to be about 80%.

World Industry Structure

Principal world columbium and tantalum raw material and product producers are listed in tables 8 and 9, respectively. Annual world production of columbium and tantalum mineral concentrates, by country, is listed in table 10. Brazil and Canada were the major producers of columbium mineral concentrates, and Australia, Brazil, Canada, and Mozambique were the major producers of tantalum mineral concentrates. Tantalum was also available from tantalum-bearing tin slags, which are byproducts from tin smelting, principally from Asia, Australia, and Brazil. However, their importance has decreased with the exception of accumulated inventory owing to the downsizing of the tin industry in the 1980s.

World Review

Australia.—For its 2003 financial year ending June 30, 2003, Sons of Gwalia Ltd., West Perth, Western Australia, reported that tantalum production (Ta_2O_5 contained in mineral concentrates) totaled about 993 t, and sales totaled about 953 t at its Greenbushes and Wodgina Mines. Production at Greenbushes, located approximately 300 kilometers (km) south of Perth and 80 km southeast of the port of Bunbury totaled about 476 t compared with about 530 t in 2002. For the 2003-04 financial year, Greenbushes tantalum production was planned to be about 408 t. Production at Wodgina, located approximately 100 km south of Port Hedland in the Pilbara region of Western Australia, totaled about 517 t compared with about 440 t in 2002, and was the first time in its history that production exceeded that of Greenbushes. Production capacity at Greenbushes and Wodgina totaled about 1,360 t (Sons of Gwalia Ltd., 2003, p. 1-2, 5, 9-10).

As of June 30, 2003, Sons of Gwalia reported that Greenbushes tantalum mineral resource base was about 56,100 t of contained Ta_2O_5, including about 26,000 t of contained Ta_2O_5 classified as being tantalum ore reserves, and that Wodgina's tantalum mineral resource base was about 40,300 t of contained Ta_2O_5, including about 23,200 t of contained Ta_2O_5 classified as being tantalum ore reserves (Sons of Gwalia Ltd., 2003, p. 12).

Tantalum Australia NL, Balcatta, Western Australia, announced in March that the company had reached agreements for the acquisition of two tantalum/niobium projects in the Gascoyne and Kimberley (Brockman) regions of Western Australia. The Gascoyne project, owned by Rare Resources NL and comprising two mining leases, is about 80 km northeast of Gascoyne Junction in the Arthur River and Nardoo Well area. Operation of a new jig plant at Gascoyne commenced in December, with the raw columbium and tantalum mineral concentrate production being shipped to the company's Balcatta facility for further processing. The Brockman project, owned by Aztec Resources Ltd. and comprising two mining lease applications, is located approximately 15 km southeast of Halls Creek, with columbium minerals occurring in a zone termed the "Niobium Tuff." Ore resources total approximately 50 million metric tons (Mt) grading 4,400 parts per million (ppm) Nb_2O_5 and 270 ppm Ta_2O_5 (Tantalum Australia NL, 2003a, p. 1-2, 4-5; 2003b, p. 2; 2003d).

In June, Tantalum Australia announced the signing of a long-term sales contract with the Australian subsidiary of a major U.S. aerospace components manufacturer to supply tantalum materials, including a conditional agreement to supply columbium products, which will generate a minimum sales revenue of $56 million. The contract was said to be linked to a supply agreement Tantalum Australia entered into with a European metal refining group for the supply to Tantalum Australia of tantalum and columbium products and for the supply by Tantalum Australia to the metal refining group of tantalum and columbium containing mineral concentrates.

The supply contracts will have the potential to generate estimated sales revenues of $123 million during a 3-year period (Tantalum Australia NL, 2003c).

Brazil.—Cia. Brasileira de Metalurgia e Mineração (CBMM), which was the world's largest columbium producer, reportedly supplies about 70% of the world requirements for columbium products. CBMM's Araxa Mine has a production capacity of about 84,000 metric tons per year (t/yr) of pyrochlore concentrates, which is subsequently upgraded to a concentrate containing about 65% Nb_2O_5. CBMM also has facilities to produce 75,000 t/yr of steelmaking-grade ferrocolumbium, 1,000 t/yr of vacuum-grade ferrocolumbium and nickel columbium, 150 t/yr of high-purity columbium oxide, and 60 t/yr of high-purity columbium metal. Mineracao Catalao de Goias also produces a pyrochlore concentrate that contains about 57% Nb_2O_5. The concentrate is converted to about 3,600 t/yr of steelmaking-grade ferrocolumbium (Mosheim, 2003a, p. 2).

Canada.—Production of columbium at the Niobec Mine at St. Honore, 15 km northwest of Chicoutimi, Quebec, was about 3,270 t compared with about 3,330 t in 2002. Niobec was a 50-50 joint venture between Cambior Inc. (product marketing) and Sequoia Minerals Inc., a wholly owned subsidiary of Mazarin Inc. (mine operator). Niobec produces a pyrochlore concentrate that is converted into ferrocolumbium grading 66% columbium using an aluminothermic converter. The milling capacity for ore from the mine is 3,500 metric tons per day. According to the company, "Sales were slightly lower in 2003 due to a difficult steel market in North America and a lower niobium price on world markets." The main sales markets were Europe, Japan, North America, and, for the first time, China. Sales were expected to be slightly higher in 2004. In 2003, capital expenditures totaled about $3.5 million, mainly for a new tailings pond and underground mobile equipment and infrastructure development. At yearend, mineral reserves at the mine totaled an estimated 22.6 Mt at an average grade of 0.65% Nb_2O_5, which was little change from yearend 2002, compared with an estimated 11.9 Mt at an average grade of 0.73% Nb_2O_5 at yearend 2000. Mineral reserves were sufficient for at least 18 years of mine life at the current mining rate (Cambior Inc., 2004, p. 15, 19-20, 75; Sequoia Minerals Inc., 2004, p. 8-9, 13, 32).

On December 29, Mazarin Inc. carried out a corporate reorganization whereby its industrial minerals division, which included the company's 50% interest in the Niobec Mine, became an independent company known as "Sequoia Minerals Inc." and was listed on the Toronto [Ontario, Canada] Stock Exchange (TSE) under the symbol "SEQ" (Sequoia Minerals Inc., 2004, p. 1-2, 13, 32; 2004§). In April 2004, the respective boards of directors of Cambior and Sequoia unanimously approved a proposed merger transaction. A formal merger agreement was signed in late May. Sequoia would become a wholly owned subsidiary of Cambior, and Cambior would acquire Sequoia's 50% interest in the Niobec Mine along with full operatorship. The merger was expected to take effect on July 2, 2004, with Sequoia common shares delisted from the TSE shortly thereafter (Cambior Inc. and Sequoia Minerals Inc., 2004; 2004a§, b§).

In 2003, about 67 t of Ta_2O_5 contained in concentrate was produced at the Bernic Lake, Manitoba, tantalum operation compared with about 71 t in 2002.

Japan.—In 2003, Japan's demand for tantalum was 444 t (powder, 219 t; compounds, 109 t; and products, 116 t) compared with 371 t in 2002. In 2004, tantalum demand was forecast to be about 461 t; powder, 225 t; compounds, 114 t; and products, 122 t. Forecast growth for tantalum powder was attributed to higher demand for tantalum capacitors in digital video devices, personal computers, and cellular telephones. Tantalum imports (powder, compounds, and products) in 2003 were 112 t compared with 105 t in 2002. Tantalum imports in 2004 were expected to be 113 t. Tantalum exports (metal and powder) in 2003 were about 252 t compared with about 108 t in 2002; Asia and the European Union were the major recipients of the exports (Roskill's Letter from Japan, 2004a).

In 2003, Japan's apparent consumption of tantalum capacitors increased by more than 10% to 5,400 million units. Production of tantalum capacitors increased to 5,320 million units from 4,720 million units in 2002 and exports increased to 2,630 million units from 2,120 million units. Tantalum capacitor imports were 2,710 million units compared with 2,270 million units in 2002 and accounted for 50% of tantalum capacitor apparent consumption. Imports reflected a rise in shipments from Japanese facilities operated overseas; China and Thailand accounted for almost 80% of total imports (Roskill's Letter from Japan, 2004a, b).

Outlook

Columbium.—The principal use for columbium will continue to be as an additive in steelmaking, mostly in the manufacture of microalloyed steels used for automobiles, bridges, pipelines, and so forth. However, less than 10% of steel produced in the world has been estimated to benefit from the advantages of columbium addition (Roskill Information Services, 2002a, p. 3). The production of high-strength low alloy steel is the leading use for columbium, and the trend for columbium demand, domestically and globally, will continue to follow closely that of steel production. (Additional information about the future of the steel industry can be found in the USGS Minerals Yearbook chapter on iron and steel.) Global consumption of finished steel products was projected to increase by 6.2% in 2004 and by 4.5% in 2005. Steel consumption in China was estimated to increase by 13.1% in 2004 and by 10.4% in 2005. China's share of global steel consumption was estimated to increase to 30.3% in 2005 from 13.5% in 1995. Steel consumption in the rest of the world, excluding China, was estimated to increase by 3.6% in 2004 and by 2.2% in 2005. Steel consumption in the United States was estimated to increase by 4.6%, at an average annual rate of 1.5%, from 2003 through 2005 (International Iron and Steel Institute, 2004§).

The outlook for columbium also will be dependent on the performance of the aerospace industry and its use of columbium-bearing alloys. Columbium consumption in the production of superalloys, which is the second largest end use for columbium, will be most dependent on the market for aircraft engines. Nickel-base superalloys (such as alloy 718, which contains about 5% columbium) can account for about 40% to 50% of engine weight, and they are expected to be the materials of choice for the future owing to their high-temperature operating capability (Cunningham, 2004a, p. 17).

Tantalum.—U.S. apparent consumption of tantalum totaled about 500 t in 2003, about the same as in 2002. More than 60% of the tantalum consumed was used to produce electronic components, mainly tantalum capacitors. This market sector is expected to be stimulated by the growth in the use of cellular telephones; each phone may contain from 10 to 20 capacitors (Mining Journal, 2000). Tantalum capacitor demand is projected to grow by about 9% to 10% per year through 2005. For the near term, tantalum carbide in the metal cutting industry is expected to grow at an estimated 5% per year (Roskill Information Services Ltd., 2002b, p. 1-4, 124-176).

An important component of world tantalum supply is the U.S. Government sales of tantalum materials from the NDS. As of May 31, 2004, tantalum materials authorized for disposal from the NDS totaled about 571 t of contained tantalum, including about 517 t contained in tantalum minerals.

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TABLE 1

SALIENT COLUMBIUM STATISTICS[1]

		1999	2000	2001	2002	2003
United States:						
Government stockpile releases, columbium content[2]	metric tons	280	217	-4	9	223
Production of ferrocolumbium, columbium content	do.	NA	NA	NA	NA	NA
Exports, columbium metal, compounds, alloys, gross weight	do.	NA	NA	NA	NA	NA
Imports for consumption:						
Mineral concentrates, columbium content[e]	do.	140	300	290	290	180
Columbium metal and columbium-bearing alloys, columbium content[e]	do.	468	607	1,050	673	743
Columbium oxide, columbium content[e]	do.	1,200	1,190	1,360	660	590
Ferrocolumbium, columbium content[e]	do.	4,450	4,400	4,480	4,030	4,080
Tin slag, columbium content	do.	NA	NA	NA	NA	NA
Consumption:						
Raw materials, columbium content	do.	NA	NA	NA	NA	NA
Ferrocolumbium and nickel columbium, columbium content[e]	do.	3,460	4,090	4,230	3,150	3,650
Apparent, columbium content[e]	do.	4,100	4,300	4,400	4,100	4,300
Prices:						
Columbite[3, 4]	dollars per pound	3.00	6.25	NA	NA	NA
Ferrocolumbium[5]	do.	6.88	6.88	6.88	6.60	6.58
Pyrochlore[6]	do.	NA	NA	NA	NA	NA
World, production of columbium-tantalum concentrates, columbium content[e]	metric tons	24,600 r	24,800 r	31,100 r	32,800 r	32,800

[e]Estimated. [r]Revised. NA Not available.

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

[2]Net quantity (uncommited inventory). Negative numbers indicate an increase in inventory.

[3]Yearend average value, contained pentoxides for material having a columbium pentoxide to tantalum pentoxide ratio of 10 to 1.

[4]The published price for columbite ore was discontinued in October 2001 at a range of $5.50 to $7.00 per pound of pentoxide content.

[5]Yearend average value of contained columbium, standard (steelmaking) grade.

[6]Yearend average value of contained pentoxide.

TABLE 2
SALIENT TANTALUM STATISTICS

		1999	2000	2001	2002	2003
United States:						
Government stockpile releases, tantalum content[1]	metric tons	5	242	-53	16	335
Exports:						
Tantalum ores and concentrates, gross weight[2]	do.	299	263	530	232	295
Tantalum metal, compounds, alloys, gross weight	do.	460	460	486	265	187
Tantalum and tantalum alloy powder, gross weight	do.	90	108	156	188	280
Imports for consumption:						
Mineral concentrates, tantalum content[e]	do.	320	650	690	710	490
Tantalum metal and tantalum-bearing alloys, tantalum content[3]	do.	244	251	316	266	249
Tin slag, tantalum content	do.	NA	NA	NA	NA	NA
Consumption:						
Raw materials, tantalum content	do.	NA	NA	NA	NA	NA
Apparent, tantalum content[e]	do.	555	650	550	500	500
Prices, tantalite[4]	dollars per pound	34	220	37	31	28
World, production of columbium-tantalum concentrates, tantalum content[e]	metric tons	656 [r]	1,070 [r]	1,180 [r]	1,480 [r]	1,210

[e]Estimated. [r]Revised. NA Not available.
[1]Net quantity (uncommited inventory). Negative numbers indicate an increase in inventory.
[2]Includes reexports.
[3]Exclusive of waste and scrap.
[4]Yearend average value of contained pentoxides.

TABLE 3

COLUMBIUM AND TANTALUM MATERIALS IN NATIONAL DEFENSE STOCKPILE INVENTORIES AS OF DECEMBER 31, 2003[1]

(Metric tons of columbium or tantalum content)

			Uncommitted			
Material	Stockpile goal[2]	Disposal authority	Stockpile-grade	Nonstockpile-grade	Total	Committed
Columbium:						
Concentrates	--	372	351	21	372	119
Carbide powder	--	--	--	--	--	--
Ferrocolumbium	--	--	--	--	--	--
Metal ingots	--	37	37	--	37	--
Total	--	408	387	21	408	119
Tantalum:						
Minerals	--	577	541	36	577	184
Carbide powder	--	6	6	--	6	--
Metal:						
Capacitor grade	--	17	17	--	17	16
Ingots	--	9	9	--	9	17
Oxide	--	19	19	--	19	--
Total	--	628	592	36	628	217

-- Zero.

[1]Data may not add to totals shown because of independent rounding.

[2]Goal effective as of December 28, 2001.

Source: Defense National Stockpile Center.

TABLE 4

REPORTED CONSUMPTION, BY END USE, AND INDUSTRY STOCKS OF FERROCOLUMBIUM AND NICKEL COLUMBIUM IN THE UNITED STATES[1]

(Metric tons of columbium content)

End use	2002	2003
Steel:		
Carbon	705	820
Stainless and heat-resisting	529	612
Full alloy	(2)	(2)
High-strength low alloy	1,100 r	1,280
Electric	(2)	(2)
Tool	(2)	(2)
Unspecified	--	--
Total	2,330	2,710
Superalloys	813	933
Alloys (excluding alloy steels and superalloys)	(3)	(3)
Miscellaneous and unspecified	9	8
Grand total	3,150	3,650
Stocks, December 31:		
Consumer	NA	NA
Producer[4]	NA	NA
Total	NA	NA

[r]Revised. NA Not available. -- Zero.

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

[2]Included with "Steel, High-strength low alloy."

[3]Included with "Miscellaneous and unspecified."

[4]Ferrocolumbium only.

TABLE 5

U.S. FOREIGN TRADE IN COLUMBIUM AND TANTALUM METAL AND ALLOYS, BY CLASS[1]

Class	2002 Gross weight (metric tons)	2002 Value (thousands)	2003 Gross weight (metric tons)	2003 Value (thousands)	Principal destinations and sources, 2003 (gross weight in metric tons and values in thousand dollars)
Exports:[2]					
Columbium:					
Ores and concentrates	64	$435	170	$1,270	France 96, $1,030; Japan 14, $133; China 39, $79; Mexico 20, $13; Italy 1, $10; Canada [3], $3.
Ferrocolumbium	126	1,500	143	1,430	Canada 116, $1,130; Mexico 23, $257; Philippines 1, $19; Taiwan [3], $5; Colombia[3], $3.
Tantalum:					
Synthetic concentrates	74	63	70	174	China 2, $85; Mexico 44, $25; Japan [3], $19; Bahamas 7, $11; United Kingdom 1, $5.
Ores and concentrates	232	1,950	295	4,190	Belgium 104, $1,300; Brazil 139, $989; Germany 10, $966; China 23, $528; Spain 11, $250; Portugal 4, $92.
Unwrought and waste and scrap	59	3,940	46	2,830	Germany 13, $858; China 17, $777; United Kingdom 5, $472; Australia 5, $237; Canada 3, $211; Austria 1, $80.
Unwrought powders	188	109,000	280	154,000	United Kingdom 100, $74,800; Israel 113, $68,900; Germany 36, $5,730; Sweden 18, $2,110; Japan 10, $1,720; El Salvador 1, $337; China 1, $330.
Unwrought alloys and metal	16	5,600	22	6,170	United Kingdom 7, $3,310; Austria 4, $660; Germany 4, $579; Israel 2, $536; Japan 3, $411; Portugal 1, $328; France 3, $279.
Wrought	190	96,200	119	62,200	Japan 41, $13,400; Germany 23, $9,930; United Kingdom 11, $9,540; Israel 15, $8,760; Taiwan 3, $7,460; France 11, $5,450; Singapore 2, $2,770; Thailand 5, $1,800.
Total	XX	219,000	XX	232,000	United Kingdom, $88,100; Israel, $78,800; Germany, $18,100; Japan, $15,800; Taiwan, $7,470; France, $6,930; Singapore, $2,770; Sweden, $2,380.
Imports for consumption:					
Columbium:					
Ores and concentrates	22	326	23	610	Kazakhstan 14, $399; China 9, $210.
Oxide	935	14,600	837	12,200	Estonia 290, $3,860; Brazil 246, $3,070; Germany 53, $2,220; Russia 155, $1,810; China 73, $994; Spain 20, $220.
Ferrocolumbium	6,200	52,500	6,280	54,700	Brazil 5,420, $46,600; Canada 834, $7,850; Germany 24, $260.
Unwrought alloys, metal, and powder	673	19,000	743	16,400	Brazil 500, $9,640; Germany 110, $2,360; Kazakhstan 63, $2,230; Estonia 41, $1,430; China 10, $202; Hong Kong 16, $192.
Tantalum:					
Synthetic concentrates	--	--	(3)	10	All from China.
Ores and concentrates	2,400	83,500	1,580	60,100	Australia 1,320, $55,700; Canada 250, $4,420; China [3], $17; Russia[3], $5; Austria[3], $4.
Unwrought waste and scrap	285	17,100	224	12,800	Japan 50, $3,980; Israel 46, $2,100; Germany 24, $1,950; Mexico 22, $850; Austria 7, $750; China 24, $627; United Kingdom 14, $591.
Unwrought powders	105	24,600	171	38,400	Japan 22, $14,800; Germany 62, $11,600; China 64, $7,380; Thailand 19, $4,250; United Kingdom 4, $330.
Unwrought alloys and metal	110	9,340	46	6,480	Kazakhstan 31, $3,850; Japan 5, $856; Germany 4, $719; China 5, $570; Austria 1, $369; Hong Kong 1, $66.
Wrought	51	10,900	32	7,760	Kazakhstan 19, $3,100; China 6, $2,380; Japan 5, $1,120; Austria 1, $451; Germany [3], $234; Canada 1, $217; United Kingdom 1, $131.
Total	XX	232,000	XX	209,000	Brazil, $59,300; Australia, $55,700; Japan, $20,900; Germany, $19,300; Canada, $12,500; China, $12,400; Kazakhstan, $9,600; Estonia, $5,610.

XX Not applicable. -- Zero.

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

[2]For columbium, data on exports of metal and alloys in unwrought and wrought form, including waste and scrap, are not available; included in nonspecific tariff classification.

[3]Less than 1/2 unit.

Sources: U.S. Census Bureau and U.S. Geological Survey.

TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF COLUMBIUM ORES AND CONCENTRATES, BY COUNTRY[1]

	2002		2003	
Country	Gross weight (metric tons)	Value (thousands)	Gross weight (metric tons)	Value (thousands)
China	7	$152	9	$210
Japan[2]	16	174	--	--
Kazakhstan	--	--	14	399
Total	22	326	23	610

-- Zero.

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

[2]Presumably country of transshipment rather than original source.

Sources: U.S. Census Bureau and U.S. Geological Survey.

TABLE 7
U.S IMPORTS FOR CONSUMPTION OF TANTALUM ORES AND CONCENTRATES, BY COUNTRY[1]

Country	2002		2003	
	Gross weight (metric tons)	Value (thousands)	Gross weight (metric tons)	Value (thousands)
Australia	1,920	$71,600	1,330	$55,700
Austria[2]	--	--	(3)	4
Bolivia	3	77	--	--
Brazil	66	1,150	--	--
Canada	250	5,500	250	4,420
China	2	224	(3)	17
Cote d'Ivoire	1	46	--	--
Mozambique	34	909	--	--
Netherlands[2]	1	50	--	--
Nigeria	29	670	--	--
Russia	(3)	11	(3)	5
Rwanda	34	809	--	--
Sierra Leone	10	40	--	--
South Africa	1	79	--	--
Zimbabwe	42	2,330	--	--
Total	2,400	83,500	1,580	60,100

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Presumably country of transshipment rather than original source.
[3]Less than 1/2 unit.

Sources: U.S. Census Bureau and U.S. Geological Survey.

TABLE 8

PRINCIPAL WORLD COLUMBIUM AND TANTALUM RAW MATERIAL PRODUCERS

Country	Company and/or mine	Material type
Mining of columbium- and tantalum-bearing ores:		
Australia	Sons of Gwalia Ltd. (Greenbushes)	Columbium-tantalum.
Do.	Sons of Gwalia Ltd. (Wodgina)	Tantalum.
Brazil	Cia. Brasileira de Metalurgia e Mineracao (CBMM) (Araxa)	Columbium.
Do.	Cia. de Estanho Minas Brasil (MIBRA)[1]	Columbium-tantalum.
Do.	Paranapanema S.A. Mineracao Industria e Construcao (Pitinga)	Do.
Do.	Mineracao Catalao de Goias S.A. (Catalao)	Columbium.
Canada	Cambior Inc. and Mazarin Inc. (Niobec)	Do.
Do.	Tantalum Mining Corp. of Canada Ltd. (Tanco)[2]	Tantalum.
China	Government-owned	Columbium-tantalum.
Production of columbium- and tantalum-bearing tin slags:		
Australia	Sons of Gwalia Ltd. (Greenbushes)	Do.
Brazil	Cia. Industrial Fluminense[1]	Do.
Do.	Mamoré Mineracao e Metalurgia[3]	Do.
Thailand	Thailand Smelting and Refining Co. Ltd. (Thaisarco)	Do.
Production capacity for columbium- and tantalum-bearing synthetic concentrates, Germany, western states	H.C. Starck GmbH & Co. KG	Do.

[1]A wholly owned subsidiary of Metallurg Inc., New York, NY.

[2]A wholly owned subsidiary of Cabot Corp.

[3]A subsidiary of Paranapanema S.A. Mineracao Indústria e Construcao.

TABLE 9

PRINCIPAL WORLD PRODUCERS OF COLUMBIUM AND TANTALUM PRODUCTS

Country	Company	Products[1]
Austria	Treibacher Industrie AG	Nb and Ta oxide/carbide, FeNb, and NiNb.
Brazil	Cia. Brasileira de Metalurgia e Mineracao (CBMM)	Nb oxide/metal, FeNb, and NiNb.
Do.	Cia. Industrial Fluminense[2]	Nb and Ta oxide.
Do.	Mineracao Catalao de Goias S.A. (Catalao)	FeNb.
Canada	Cambior Inc. and Mazarin Inc. (Niobec)	FeNb.
Estonia	Silmet	Nb oxide/metal.
Germany, western states	Gesellschaft fur Elektrometallurgie mbH (GFE)[2]	FeNb and NiNb.
Do.	H.C. Starck GmbH & Co. KG	Nb and Ta oxide/metal/carbide, K-salt, FeNb, NiNb, and Ta capacitor powder.
Japan	Mitsui Mining & Smelting Co.	Nb and Ta oxide/metal/carbide.
Do.	Cabot Supermetals[3]	Ta capacitor powder.
Do.	H.C. Starck-V Tech Ltd.[4]	Ta capacitor powder.
Kazakhstan	Ulba Metallurgical	Ta oxide/metal.
Do.	Irtysh Chemical & Metallurgical Works	Nb oxide/metal.
Russia	Solikamsk Magnesium Works	Nb and Ta oxide.
Thailand	H.C. Starck (Thailand) Co. Ltd.[4]	K-salt and Ta metal.
United States	Cabot Supermetals[3]	Nb and Ta oxide/metal, K-salt, and Ta capacitor powder.
Do.	H.C. Starck Inc.[5]	Nb and Ta metal, and Ta capacitor powder.
Do.	Kennametal Inc.	Nb and Ta carbide.
Do.	Reading Alloys Inc.	FeNb and NiNb.
Do.	Wah Chang[6]	Nb metal and FeNb.

[1]Nb, columbium; Ta, tantalum; FeNb, ferrocolumbium; NiNb, nickel columbium; K-salt, potassium fluotantalate; oxide, pentoxide.

[2]A wholly owned subsidiary of Metallurg Inc., New York, NY.

[3]A wholly owned subsidiary of Cabot Corp.

[4]A subsidiary of H.C. Starck GmbH & Co. KG.

[5]Jointly owned by Bayer Corp. and H.C. Starck GmbH & Co. KG.

[6]A subsidiary of Allegheny Technologies Inc.

TABLE 10

COLUMBIUM AND TANTALUM: ESTIMATED WORLD PRODUCTION OF MINERAL CONCENTRATES, BY COUNTRY[1, 2]

(Metric tons)

Country[5]	Gross weight[3]					Columbium content[4]					Tantalum content[4]				
	1999	2000	2001	2002	2003	1999	2000	2001	2002	2003	1999	2000	2001	2002	2003
Australia, columbite-tantalite	1,230	1,600	2,220	3,100	2,500	140	160	230	290	230	350	485	660	940	765
Brazil:															
Pyrochlore	52,100	51,900	65,000 r	68,800 r	69,000	21,900	21,800	27,300 r	28,900 r	29,000	--	--	--	--	--
Tantalite	590	680	750	680 r	715	NA	NA	NA	NA	NA	165	190	210	190 r	200
Burundi	42 [6]	31 [6]	123 [6]	72 r, 6	70	NA	NA	NA	NA	NA	10	8	32	15 r	14
Canada:															
Pyrochlore	5,240	5,070	7,070	7,410 r	7,270	2,360	2,280	3,180	3,330 r	3,270	--	--	--	--	--
Tantalite	208	228	308	232	220	10	11	15	12	11	54	57	77	58	55
Congo (Kinshasa), columbite-tantalite	NA	450	200	100 r	50	NA	110	50	25 r	13	NA	130	60	30 r	15
Ethiopia, tantalite	50 [6]	65 [6]	47 r	61 r	60	5	7	5 r	6	6	29	38	28 r	35	35
Mozambique	--	25 r, 6	27 [6]	47 r, 6	189 [6]	--	5 r	5	8 r	34	--	10 r	11	19 r	75
Namibia	NA	2	5	9	18	NA	1	(7)	(7)	1	NA	1	3	6	11
Nigeria, columbite-tantalite	300 r	469 r	610 r	500 r	450	125 r	200 r	250 r	210 r	190	15 r	23 r	30 r	25 r	23
Rwanda	147 [6]	561 [6]	241 [6]	96 r, 6	70	46	176	76	30 r	22	33	124	53	20 r	14
Uganda	--	3 [6]	11 [6]	6 r, 6	6	--	1	5 r	3	3	--	1	3 r	2 r	2
Zimbabwe	NA	NA	30	480	4 [6]	NA	NA	NA	NA	NA	NA	NA	9	144	1
Total	59,900 r	61,100 r	76,600 r	81,600 r	80,600	24,600 r	24,800 r	31,100 r	32,800 r	32,800	656 r	1,070 r	1,180 r	1,480 r	1,210

rRevised. NA Not available. -- Zero.

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

[2]Excludes production of columbium and tantalum contained in tin ores and slags. Table includes data available through July 9, 2004.

[3]Data on gross weight generally have been presented as reported in official sources of the respective countries, divided into concentrates of columbite, tantalite, and pyrochlore where information is available to do so, and reported in groups, such as columbite and tantalite, where it is not.

[4]Unless otherwise specified, data presented for metal content are estimates based on, in most part, reported gross weight and/or pentoxide content.

[5]In addition to the countries listed, Bolivia, China, Cote d'Ivoire, French Guiana, Russia, and Zambia also produce or are believed to produce columbium and tantalum mineral concentrates, but available information is inadequate to make reliable estimates of output levels.

[6]Reported figure.

[7]Less than 1/2 unit.

FIGURE 1
MAJOR SOURCES OF U.S. COLUMBIUM IMPORTS

(Columbium content)

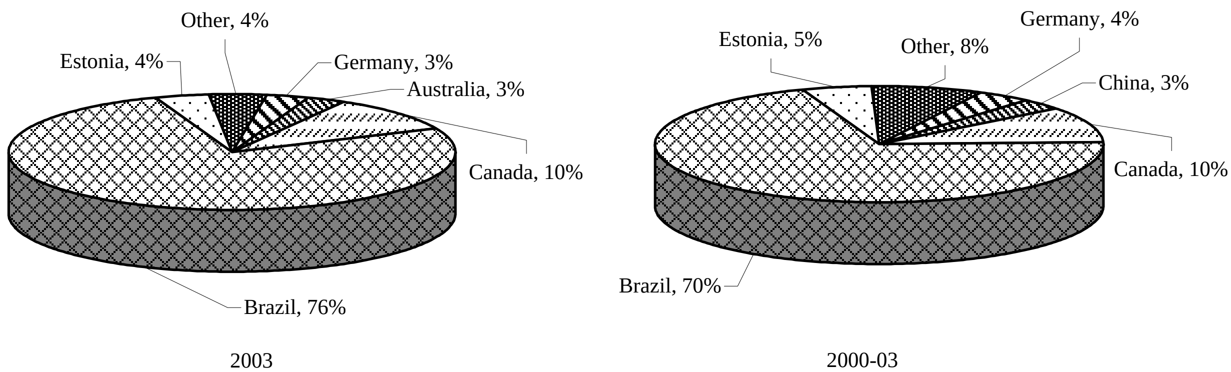
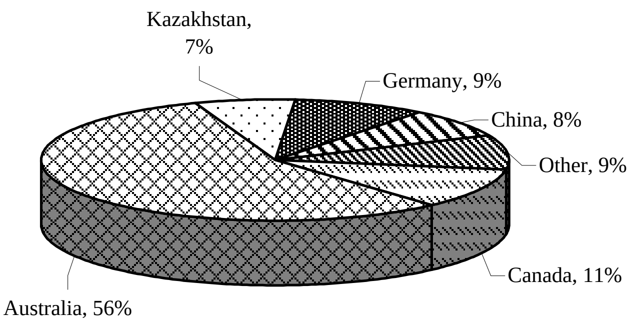
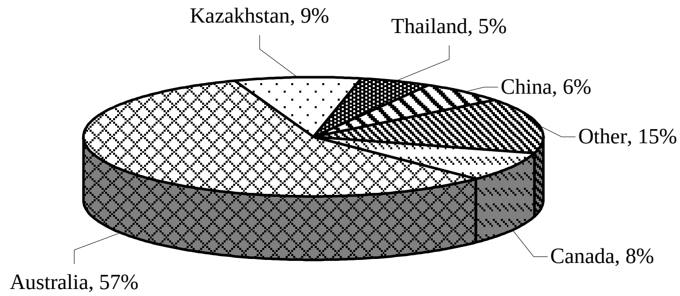


FIGURE 2
MAJOR SOURCES OF U.S. TANTALUM IMPORTS

(Tantalum content)



2003



2000-03