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NIOBIUM (COLUMBIUM) AND TANTALUM

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NIOBIUM (COLUMBIUM) AND TANTALUM

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In 2009, U.S. niobium apparent consumption (measured in contained niobium) was 4,210 metric tons (t), 50% less than that of 2008; U.S. tantalum apparent consumption (measured in contained tantalum) was 473 t, 25% less than that of 2008. No domestic mine production of niobium or tantalum ore was reported. The leading use of niobium was as an alloying element in high-strength low-alloy steel. The leading use of tantalum was in electronic capacitors.

Legislation and Government Programs

The Defense National Stockpile Center (DNSC) planned to dispose of niobium and tantalum materials under its fiscal year 2009 Annual Materials Plan (AMP) and announced the fiscal 2010 plan. The DNSC sold no niobium or tantalum materials in calendar year 2009. The DNSC's fiscal year 2010 AMP set maximum disposal goals for niobium and tantalum materials (niobium materials measured in contained niobium, and tantalum materials measured in contained tantalum) as follows: columbium metal, 4,536 kilograms (kg), and tantalum carbide, 1,814 kg (Defense National Stockpile Center, 2009, p. 1). The DNSC suspended the sale of niobium and tantalum materials while it performed a congressionally directed review of the stockpile configuration (Defense National Stockpile Center, 2008, p. 1–2).

Production

The major marketable niobium materials are ferroniobium, nickel-niobium, and niobium metal, ore, and oxide. The major marketable tantalum materials are tantalum metal, ore, and powder. In 2009, neither niobium nor tantalum domestic mine production was reported. The Kougarok prospect, on the Seward Peninsula in Alaska, hosts significant tantalum resources in a lithium-fluorine granite (Hudson, 1998, p. 151–153; Navigator Exploration Corp., 2003, p. 2).

Consumption

Domestic data for niobium and tantalum materials were developed by the U.S. Geological Survey (USGS) by means of the "Columbium (Niobium) and Tantalum," "Consolidated Consumers," and "Specialty Ferroalloys" surveys. For niobium and tantalum materials, there was one respondent to the "Columbium (Niobium) and Tantalum" canvass, about 70 respondents to "Consolidated Consumers" canvass, and one respondent to the "Specialty Ferroalloys" canvass.

In the United States, niobium was consumed by the metallurgical industry; tantalum, by the electronics industry. Niobium masteralloys—ferroniobium and niobium-nickel alloy—were consumed to produce steel and superalloys. About 75% of world niobium consumption was for the production of microalloyed steel (Companhia Brasileira de Metalurgia e Mineração, undated c). Tantalum was consumed to produce capacitors and superalloys. More than 70% of tantalum is consumed by the electronics industry, and most of that goes into making capacitors (Serjak and others, 2002).

Prices

Niobium and tantalum materials are not openly traded. Purchase contracts are confidential between buyer and seller; however, trade journals report composite prices of tantalite based on interviews with buyers and sellers, and traders declare the value of niobium and tantalum materials that they import or export.

The price of tantalite ore peaked in mid-2005 at about 10% more than the pre- and post-peak price after which it remained unchanged until it rose by more than 40% in 2007 compared with the previous 17 months unchanging price when it peaked at yearend. In 2008, the tantalite ore price remained unchanged after declining by 6% from the 2007 yearend peak price. In 2009, the price of tantalite ore continued its decline, decreasing by 22% by yearend to values similar to those reported in early 2007. The price of tantalite ore did not appear to have been driven up in 2008 as those of other metals had been; however, the subsequent decline of metal prices in 2008 and 2009 appeared to have also affected tantalite ore price.

Foreign Trade

Niobium and tantalum material exports from and imports to the United States included ferroniobium and niobium chemicals, metal, ore, and oxide, and tantalum metal and ore. In 2009, the values of foreign trade of these niobium and tantalum materials were $84 million for exports (47% less than that of 2008) and $289 million for imports (45% less than that of 2008).

The United States exported 195 t of niobium contained in niobium materials (79% less than that of 2008) and imported 4,400 t of niobium contained in niobium materials (52% less than that of 2008) (table 1). The United States exported 326 t of tantalum contained in tantalum materials (51% less than that of 2008) and imported 798 t of tantalum contained in tantalum materials (38% less than that of 2008) (table 2).

World Industry Structure

Brazil and Canada were the leading producers of niobium mineral concentrates; Australia, Brazil, Canada, China, and Mozambique were the leading producers of tantalum mineral concentrates. Tantalum-bearing tin slags, which are byproducts from tin smelting, principally from Asia, Australia, and Brazil, are another source of tantalum. The leading niobium ore and concentrate producers were Companhia Brasileira de Metalurgia

e Mineração (CBMM) in Brazil and IAMGOLD Corporation (Niobec Mine) in Canada. The leading tantalum ore and concentrate producers were Talison Minerals Pty. Ltd. (Wodgina Mine) in Australia and Metalurg Group (Mibra Mine) and Mineração Taboca S/A (Pitinga Mine) in Brazil. Other tantalum producers were Cabot Corp. (Tanco Mine) in Canada, Noventa Ltd. (Morropino Mine) in Mozambique, and Yichun Tantalum Co., Ltd. (Yichun Mine) in China.

As much as 97% of 2008 world niobium production resulted from the mining pyrochlore mineral [$(Na,Ca)_2Nb_2O_6(OH,F)$] in Brazil and Canada. Steelmaking, primarily high-strength low-alloy and stainless steels, accounted for about 90% niobium use. The niobium-containing high-strength low-alloy steel was use in automobiles, construction, and gas pipelines; the stainless steel in automobiles (Roskill Information Services Ltd., 2009a, p. 1–3).

About 70% of 2008 tantalum world production resulted from the mining of tantalum-containing minerals with an additional 7% from synthetic tantalum ore and the remainder from recycling (Roskill Information Services Ltd., 2009b, p. 8).

The tantalum industry, traditionally shrouded in secrecy, is comprised of (in order of material flow) a mining component that typically extracts ore and produces a concentrate, a processing segment that converts concentrate into an oxide or metal, a parts manufacturing segment that uses the oxide or metal material to produce such components as capacitors or superalloys, and a product manufacturing sector that uses the parts, such as capacitors, in electronic devices, such as cellular telephones (Firman, 2008). World supply by source in 2008 was about 71% from primary production (mining), 20% from recycling, 7% from tin slag, and 2% from inventory (Wallwork, 2008). Tantalum world consumption was estimated to have increased at an average annual rate of 6% from about 1991 through 2006 (Ruffini, 2008).

Tantalum-bearing minerals were considered to be among the "conflict minerals" [minerals identified as a driving force for the conflict in the Congo (Kinshasa)], and production, trade, processing, and use of tantalum has come under international scrutiny (Global Witness Ltd., 2009, p. 4). Transparency of material movement will probably contribute to the reduction of illicit material trade and encourage legitimate mining operations by permitting the tracing and auditing of the supply chain (Ma, 2009). Since those who trade in illicit minerals could reasonably be expected to hide the origin of their material, independent third-party verification is necessary. The Electronic Industry Citizenship Coalition and the Global e-Sustainability Initiative studied the tantalum issue and developed a process to support and promote environmentally and socially responsible practices (Electronic Industries Citizenship Coalition, 2010, p. 21–22; Resolve Inc., 2010, p. 14–19).

World Review

The USGS reported on world niobium-containing carbonatite deposits. USGS reported deposit models and grade and tonnage types based on 58 well-explored and partially mined deposits in several countries. Results were presented as figures showing the cumulative proportion of deposits versus the tonnage or grade of the deposit. About one-half of the 55 carbonatite deposits studied had 0.23% niobium pentoxide ($Nb_2O_{5)}$ average grade (Berger and others, 2009, p. 14).

Burt (2010) estimated tantalum resources by geographic area, by resource character (known, inferred, or deposit), and by host rock type based on about 100 projects. Bond estimated known resources of 153,000 t of tantalum, of which 44% was in South America, 27% in Australia, 13% in Asia, 12% in Africa, and 5% in North America. Know resources were distributed among in apogranite (61%), carbonatite (7%), pegmatite (25%), and placer (7%) host rock types. Close to 85% of production in 2002 came from pegmatite based ore bodies making them the most significant resource to production. Since they host such a large fraction of resources, apogranite hosted deposits are likely to become more important in the future. No production came from carbonatite deposits. Tantalum resources were found to be abundant and geographically distributed with Australia and Brazil being the leading host countries.

Australia.—The Government of Western Australia reported that tantalite production was 105 t of contained tantalum pentoxide (Ta_2O_5) in 2009 compared with 680 t of contained Ta_2O_5 in 2008 (Government of Western Australia, Department of Mines and Petroleum, 2010, p. 23). Australia reported that, as of December 31, 2008, Joint Ore Reserves Committee (JORC)-compliant proven and probable ore reserves (as stated in company annual reports and reports to the Australian Stock Exchange) for niobium were not available; and for tantalum, 19,000 t of contained Ta_2O_5 (Geoscience Australia, 2009, p. 5).

Talison Minerals Pty. Ltd. suspended production at the Wodgina Mine, the world's leading producing operation of tantalum ore, owing to the global financial downturn and greater market share going to central Africa, where tantalum minerals were mined under conditions of armed conflict and human rights abuses [northeastern regions of Congo (Kinshasa)]. Talison sought to educate consumers about conflict mining and to secure long-term contracts (Emery, 2010, p. 70).

Capital Mining Ltd. (Phillip) reported inferred resources of 55 million metric tons (Mt) containing niobium, among other metals, at a concentration of 80 grams per metric ton (g/t) niobium dioxide (NbO_2) at the Narraburra prospect about 12 kilometers (km) northeast of Temora, New South Wales. Capital received results from gravity separation of drill samples and planned bulk sample treatment (Capital Mining Ltd., 2010, p. 17–18).

Orion Metals Limited (East Brisbane), formerly Queensland Gold and Minerals Ltd., prospected for niobium and tantalum. At Walwa, Orion found 83 parts per million (ppm) Ta_2O_5 and 100 ppm Nb_2O_5 based on rock sampling. Orion drilled at Grants Gully (Orion Metals Limited, 2009).

Galaxy Resources Limited (Perth) prospected for tantalum at Mount Cattlin in Western Australia State near the town of Ravensthorpe. Galaxy reported proved reserves of 2.683 Mt containing 135 ppm Ta_2O_5 and probable reserves of 8.684 Mt containing 151 ppm Ta_2O_5 to a cutoff grade of 0.4% Li_2O. Galaxy reported starting mine development (Galaxy Resources Limited, 2010, p. 2–7).

Brazil.—CBMM mined niobium ore from the Barreiro carbonatite complex (19°40′ S, 46°57′ W) near Araxá, Minas Gerais State, and beneficiated the ore at the mine

site by selectively extracting the pyrochlore minerals from which niobium oxide is separated (Filho and others, 2009). The deposit contained 440 Mt of ore reserves at an average grade of 2.5% to 3% Nb_2O_5 that could be mined by open pit methods (Riffel, undated). CBMM produced ferroniobium, nickel-niobium, niobium metal, and high-purity ferroniobium, and had production capacities of 90,000 metric tons per year (t/yr) of ferroniobium, 3,000 t/yr of high-purity ferroniobium and nickel-niobium, and 210 t/yr of niobium metal (Companhia Brasileira de Metalurgia e Mineração, undated a, b). Anglo American Brazil (a subsidiary of Anglo American plc) mined pyrochlore from a carbonatite deposit. Catalão Mine (47°48′ W, 18°08′ S) is comprised of three open pit mines and a processing facility near the city of Catalão, Goiàs State. Anglo reported that Catalão mined 906,700 t of ore and processed 873,500 t of ore containing 9.3 kilograms of niobium per metric ton (kg/t) of ore to produce 5,100 t of contained niobium in 2009. JORC-compliant proved and probable reserves were 12.2 Mt at 1.17% Nb_2O_5 containing 142,000 t of niobium (Anglo American plc, 2010, p. 156, 176).

Mineração Taboca, which was acquired by MINSUR S.A. (Peru), mined columbite at the Pitinga Mine (0°47′01″ N, 60°04′43″ W) in Presidente Figueiredo Municipality, Amazon State. Taboca produced a ferroniobiumtantalum alloy containing 45% niobium, 4.5% tantalum, and 25% iron (Mineração Taboca S/A, undated a, b).

Angel Mining plc (formerly Angus & Ross plc) prospected for tantalum via St. Andrews Mining Ltd., 64% owned by Angel, at the Caiçara project in Rio Grande do Norte State. Angel liquidated St. Andrews' assets paying the former chairman with the company's remaining assets (Angus & Ross plc, 2008, p. 37; Angel Mining plc, 2009, p. 3).

Canada.—Canada reported niobium mine production of 4,330 t of contained Nb_2O_5 and tantalum mine production of 29 t of contained Ta_2O_5 in 2009 compared with 4,400 t of contained Nb_2O_5 and 53 t of contained Ta_2O_5 in 2008. Niobium was produced in Quebec, and tantalum, in Manitoba (Natural Resources Canada, 2009, 2010).

American Manganese Inc. (formerly Rocher Deboule Minerals Corp.) (2010) reported finding no significant niobium value in five holes at two locations on previously untested carbonatite showing about 1 km from the Lonnie carbonatite deposit in British Columbia, where previous exploration had assayed 0.20% Nb_2O_5. Avalon Rare Metals Inc. (Toronto, Ontario) (formerly Avalon Ventures Ltd.) prospected for niobium and tantalum at its Thor Lake (about 62°06′20″ N, 112°36′ W) and Separation Rapids properties. Avalon undertook metallurgical work to recover tantalum and niobium from Thor Lake core samples (Avalon Rare Metals Inc., 2010, p. 3–7).

Commerce Resources Corp. (Vancouver, British Columbia) prospected for niobium and (or) tantalum at the Blue River (east of Quesnel, British Columbia), Eldor (south of Kuujjuaq, Quebec), and Carbo (northeast of Prince George, British Columbia) properties that host carbonatite deposits. Commerce planned an NI 43–101-compliant estimate of Fir, Verity, and Upper Fir deposits, which comprise the Blue River project (Commerce Resources Corp., 2010). Commerce estimated that, at a cutoff grade of 150 g/t tantalum, the Upper Fir deposit contained 8.6 Mt of indicated resources at a grade of 209 g/t Ta_2O_5 and 1,373 g/t Nb_2O_5 content per metric ton of ore and inferred resources of 5.5 Mt at 208 g/t Ta_2O_5 content per metric ton of ore and 1,350 g/t Nb_2O_5 (Gorham, 2007, p. 39).

IAMGOLD mined niobium contained in pyrochlore mineral from the Saint-Honoré carbonatite deposit at the Niobec Mine (about 48°32′ N, 71°09′ W) 15 km northwest of Chicoutimi, Quebec. Niobec mill production capacity was 4,500 t/yr of niobium. The mill produced concentrate, from which Niobec produced Nb_2O_5 that was then converted to standard grade (66% niobium) ferroniobium by aluminothermic reduction. IAMGOLD expected to complete a paste backfill plant and mill expansion in 2010. The mill expansion was to increase throughput by 24%. IAMGOLD reported that niobium mine production in 2009 was 4,100 t of contained niobium compared with 4,400 t in 2008 and 4,300 t in 2007. IAMGOLD reported 32.086 Mt of proven plus probable ore reserves containing 181,300 t of Nb_2O_5 (average ore grade of 0.59% Nb_2O_5). In 2009, Niobec mined 1.773 Mt of ore, milled 1.755 Mt of ore, and produced 4,106 t of niobium (IAMGOLD Corporation, 2010, p. 41, 60, 149).

Tantalum Mining Corp. of Canada Ltd. (near Lac du Bonnet, Manitoba) suspended mine production at its tantalite mine in Manitoba during fiscal year 2009 citing current ore inventory levels and other currently available ore sources as the reason (Cabot Corporation, 2010, p. 6).

Taseko Mines Limited (2009) deferred prospecting for niobium at its Aley prospect owing to economic conditions. Taseko acquired the Aley niobium prospect in northern British Columbia in 2007; however, no mention of the prospect was made in Taseko's annual report (2010a). Taseko identified the Aley niobium property as a key asset (Taseko Mines Limited, 2010b).

Niocan Inc. (2010, p. 6) reported 4.28 Mt of measured resources at an average grade of 0.72% Nb_2O_5 and 6.35 Mt of indicated resources at an average grade of 0.65% Nb_2O_5 based on a cutoff grade of 0.40% Nb_2O_5 at its S–60 niobium deposit near Oka, Quebec.

MDN Inc. (2010b, p. 62–68) completed an NI 43–101-compliant preliminary economic assessment of its Crevier Niobium project north of Lac Saint-Jean, Quebec, and reported that the property (49°30′ N, 72°49′ W) had indicated resources of 25.75 Mt containing 0.186% Nb_2O_5 and 199 ppm Ta_2O_5. MDN estimated a 25-year mine life starting with open pit production followed by underground mining. MDN projected production of 1.133 t/yr of Nb_2O_5 and 220 t/yr of K_2TaF_2 from 1 million metric tons per year (Mt/yr) run-of-mine ore production. MDN planned a feasibility study with the objective of commercializing the niobium and tantalum resource (MDN Inc., 2010a, p. 59).

Sarissa Resources Inc. (2009a) purchased the Nemegosenda property (48°00′ N, 83°06′ W) in Ontario, which was reported to have niobium minerals (Sage, 1987). Sarissa verified that niobium mineralization extended to the east of the Hawke Zone and that a magnetic anomaly was found to the south of what was thought to have been the southern boundary of mineralized zone (Sarissa Resources Inc. 2009b, c).

China.—The leading tantalum mining areas were at Yichun, Jiangxi Province, and Nanping, Fujian Province (Fetherston, 2004, p. 78–79). TiChun Tantalum & Niobium Mine (27°38′58.10″ N, 114°31′4.06″ E) produced tantalum and niobium concentrate (Yichun Tantalum Co., Ltd., undated).

King-Tan Tantalum Industry Co. Ltd. in Shishi Industrial Zone, Yifeng County, Jiangxi Province, produced niobium and tantalum products (King-Tan Tantalum Industry Co. Ltd., undated). Ningxia Non-ferrous Metals Smeltery (a state-owned enterprise) produced niobium and tantalum products (Ningxia Non-ferrous Metals Import & Export Corp., undated).

Congo (Kinshasa).—Katanga, Kivu, Maniema, and Orientale Provinces in the eastern part of Congo (Kinshasa) host columbite-tantalite deposits known locally as coltan (Fetherston, 2004, p. 71). Shamika Resources Inc. (Montreal, Quebec, Canada) prospected for tantalum and niobium through Shamika Congo Kalehe SPRL (Shamika Resources Inc., undated).

Egypt.—Tantalum Egypt JSC [Gippsland Ltd. (Claremont, Australia) and the Government of Egypt] planned to mine tantalite from the Abu Dabbab and Nuweibi deposits. Gippsland reported Abu Dabbab (25°20′59.42″ N, 34°13′30.07″ E) reserves were 15.2 Mt at 260 g/t Ta_2O_5 proven and 15.04 Mt at 250 g/t Ta_2O_5 probable; resources were 15.2 Mt at 290 g/t Ta_2O_5 measured, 17.3 Mt at 250 g/t Ta_2O_5 indicated, and 12 Mt at 200 g/t Ta_2O_5 inferred. At Nuweibi (25°12′3.09″ N, 34°29′56.15″ E), resources were 48 Mt at 147 g/t Ta_2O_5 indicated and 50 Mt at 140 g/t Ta_2O_5 inferred. H.C. Stark Group GmbH (Goslar, Germany) committed to buy 300,000 kg/yr of contained Ta_2O_5 for the first 10 years. Gippsland estimated mine development cost at $175 million and planned to produce a concentrate containing 55% Ta_2O_5. Producing a concentrate reduces transportation cost and limits combined uranium (as U_3O_8) and thorium (as ThO_2) to less than 0.1% (Gippsland Ltd., 2009, p. 7–12).

Gabon.—Eramet Group considered developing the Mabounié deposit (Eramet Group, 2010, p. 70).

Greenland.—The Motzfeldt intrusion, a part of the Igaliko complex of southern Greenland, hosts localized niobium and tantalum mineralization associated with pyrochlore (McCreath, 2009). Ram Resources Limited (Perth, Australia) planned to acquire the Motzfeldt project (near 81°15′ N, 46° W) and to conduct a drilling program there (Fetherston, 2004, p. 69, 71–82; Ram Resources Limited, 2010, p. 1).

Malawi.—Globe Metals & Mining Limited (West Perth, Australia) (2009a, p. 4–10) reported updated resources for the Kanyika Niobium project (about 12°38′ S, 33°38′ E). At a cutoff grade of 0.15% Nb_2O_5, Globe reported JORC-compliant indicated resources of 13.2 Mt containing 48,590 t of Nb_2O_5 (0.36% average grade) and 2,120 t of Ta_2O_5 (0.016% average grade), and inferred resources of 42.1 Mt containing 117,900 t of Nb_2O_5 (0.28% average grade) and 5,470 t Ta_2O_5 (0.013% average grade). Globe planned to improve its resource estimate, to validate a process flowsheet previously developed in a scoping study, and to demonstrate ferroniobium production. Globe (2009b, p. 9, 14, and 16) estimated that for a capital expenditure of $151.7 million it will probably produce 3,000 t/yr of niobium contained in ferroniobium, 194 t of Ta_2O_5, and uranium oxide. Globe and Thuthuka Group Limited (Gauteng, South Africa) (TGL) formed a joint venture to develop the Kanyika property. Globe and TGL planned to develop a bankable feasibility study in support of production planned to start up in 2012 (Thuthuka Group Limited, 2009).

Mozambique.—Noventa Limited (St. Helier, United Kingdom) reported probable reserves of 7.80 Mt containing 2,255 t of Ta_2O_5 at Marropinno (16°30′ S, 37°54′ E) and 3.61 Mt containing 1,673 t of Ta_2O_5 at Morrua (16°16′ S, 37°52′ E) (Noventa Limited, 2007, p. 127–129). Noventa put Marropino Mine, which had been operating intermittently since 2003, on care-and-maintenance status in May and planned to restart production from tailings in 2010 with a modified plant and mine plan. The Marropino Mine was connected to the national power grid. Review of the production process found that process recovery, anticipated to be 60%, was only 30%. It was found that about one-half of the run-of-mine ore was too big to be processed and that the ore size distribution needed to be reduced. A comminution circuit was added to address this problem. Mineralogical, textural, and chemical work showed that recovery could be improved by reducing particle size to less than 1 millimeter and that the tantalum grains do not appear to be included in the mica, permitting the mica to be removed early in the beneficiation process (Noventa Limited, 2010a, p. 8–13; c). Noventa planned to restart production in 2010 (Noventa Limited, 2010b).

Pacific Wildcat Resources Corp. (Canada), a mineral exploration company, acquired Tantalum Mineracao e Prospeccas Limitada, which held licenses for tantalum exploration in the Alto Lingonha belt, Zambezi Provence (about 15°45′10″ S, 33°15′10″ E) near the Muiane Mine, a historical tantalum producer. Pacific also purchased a tantalum treatment plant (Pacific Wildcat Resources Corp., 2010a, b).

Saudi Arabia.—Tertiary Minerals plc planned to evaluate the feasibility of developing the Ghurayyah tantalum-niobium rare-earth deposit subject to receiving a new exploration license that it applied for in 2007 (Tertiary Minerals plc, 2009, p. 2, 5).

Outlook

In a study on emerging-technology driven raw materials demand, raw material production capacity development time was found to be similar to emerging-technology development time permitting raw materials supply development to take place along with emerging-technology development. Market turbulence (that is, price volatility caused by mismatched raw materials supply and demand) was posited to result from the inability of raw materials production capacity development to keep up with emerging-technology demand. This situation resulted from the inability of raw materials producers to identify emerging technologies soon enough and from the lack of information about raw material demand and manufacturing development rates for emerging technologies. Raw materials cost can be the leading cost of manufacturing in industrialized countries that depend on imported raw materials. The authors observed that world economic growth may determine the demand increase for mass-produced raw materials and, at a world economic growth rate of 3.8% per year, consumption of commodities in 2030 would be 2.4 times that of 2006. Tantalum consumption in micro capacitors and medical technology that

accounted for 39% of 2006 tantalum production was estimated to increase to 101% of 2006 tantalum production in the year 2030. Niobium consumption in micro capacitors and ferroalloys that accounted for 1% of 2006 niobium production was estimated to increase to 3% of 2006 niobium production in the year 2030 (Angerer and others, 2009).

Niobium.—The principal use for niobium was as an additive in steelmaking, mostly in the manufacture of microalloyed steels. The production of high-strength low-alloy steel was the leading use for niobium, and the trend for niobium consumption, domestically and globally, was expected to continue to closely follow that of steel production, as the steel industry is estimated to account for as much as 90% of niobium consumption. (Additional information about the steel industry can be found in the Iron and Steel chapter of the USGS Minerals Yearbook, volume I, Metals and Minerals.) Consumption of niobium, however, does not mirror trends in overall steel production, as only 10% of steel products contain niobium. The leading nonsteel use of niobium was in superalloys for, among other applications, aircraft engines.

The long-term growth of niobium use was interrupted by the economic downturn of 2008–09. Niobium is used in high-strength low-alloy steels consumed by pipeline, automobile, and construction industries. Greater demand for natural gas was expected to result in increased demand for pipeline steel. The sharp decline in demand for automobiles and in construction that started in 2008 was part of the current economic cycle. Recovery of these markets was expected to revive demand for niobium. It was reported that globally the unit consumption of niobium per metric ton of steel produced was 55 to 60 g/t, while that of highly economically developed countries was 100 g/t and of China was 40 g/t, suggesting significant potential for niobium consumption growth as China's economy develops (Roskill Information Services Ltd., 2009a, p. 124–125).

Tantalum.—Consumers relied heavily on tantalum inventories and huge quantities of highly contentious and politically sensitive, low-cost columbite and tantalite from the Congo (Kinshasa) that appeared to have displaced producers in the conventional supply chain, because an estimated 40% of tantalum mine production was put on care-and-maintenance status in 2008 and 2009 including mines in Australia, Canada, and Mozambique. The mainstream industry sought a way to exclude illegal columbite and tantalite from the supply chain. It was thought that a ban on such material by the United States and the European Union was possible. New production projects in Canada, Egypt, and Saudi Arabia offered the possibility that new mines could be brought into production between 2011 and 2013. It was anticipated that as global economy recovered, so too would demand for tantalum (Roskill Information Services Ltd., 2009b, p. 21–23).

In the midst of consumer industry concern over a possible tantalum shortage that could result from world economic recovery of demand exceeding mine production capacity development, Zogbi (2010) estimated 2009 world tantalum mine production capacity, excluding Australia and Mozambique, to be 727 t/yr of tantalum (equivalent to 845 t/yr of Ta_2O_5, 1,031 t/yr of tantalite) and recycling production to be 544 t/yr of tantalum (equivalent to 633 t/yr of Ta_2O_5, 772 t/yr of tantalite). Australian production capacity was estimated to be 854 t/yr of tantalum (equivalent to 993 t/yr of Ta_2O_5, 1,211 t/yr of tantalite) (Talison Minerals Pty. Ltd., 2007), and Mozambican, 83 t/yr of tantalum (equivalent to 96 t/yr of Ta_2O_5, 117 t/yr of tantalite) (Noventa Limited, 2010a, p. 12). Based on these estimates, 2009 world tantalum production capacity was about 3,590 t/yr of tantalum, while projected 2009 demand was 2,460 t of tantalum based on 4% annual growth rate from 2006, which was enough production capacity to meet demand with Australian production closed as was the situation. World demand for 2013 was projected to be 2,900 t of tantalum, an amount that could be met from 2009 mine and recycling production capacity.

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TABLE 1

SALIENT NIOBIUM STATISTICS[1]

		2005	2006	2007	2008	2009 [e]
United States:						
Government stockpile releases, Nb content[2, 3]	metric tons	152	156	--	--	--
Exports, Nb content[4]	do.	337	561	1,100	781	195
Imports for consumption:						
Mineral concentrates, Nb content	do.	142	120	109	134	41
Niobium metal, gross weight[5]	do.	1,380	1,450	864	1,130	699
Niobium oxide, Nb content[e]	do.	661	760	744	852	742
Ferroniobium, Nb content[e]	do.	5,430	8,150	8,400	7,120	2,920
Reported consumption, Nb content						
Raw materials	do.	W	W	W	W	W
Ferroniobium and nickel niobium[e]	do.	4,600	5,050	6,510	5,380 [r]	4,350
Apparent consumption, Nb content	do.	7,430	10,100	9,020	8,450	4,210
Price,[6] ferroniobium[7] Nb content	dollars per kilogram	14.5	NA	NA	NA	NA
Value:[8]						
Niobium ores and concentrates (gross weight)	do.	9.70	13.71	22.55	26.70	59.86
Niobium oxide (gross weight)	do.	14.12	14.07	17.64	25.65	27.30
Ferroniobium (gross weight)	do.	8.66	9.13	13.88	21.29	23.59
World, production of niobium-tantalum concentrates, Nb content	metric tons	43,100 [r]	52,800 [r]	62,000 [r]	63,000 [r]	62,900 [e]

[e]Estimated. [r]Revised. do. Ditto. NA Not available. W Withheld to avoid disclosing company proprietary data. -- Zero.

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

[2]Release is the decrease of uncommitted inventory relative to the previous calendar year.

[3]To estimate Nb content, it was assumed that natural tantalum and synthetic tantalum-niobium ores and concentrates are 16% niobium pentoxide (Nb_2O_5); niobium ores and concentrates are 30% Nb_2O_5; and Nb_2O_5 is 69.9% Nb.

[4]Includes natural and synthetic niobium ore and concentrates, niobium oxide, niobium ferroalloy, and unwrought niobium metal and alloys.

[5]Includes niobium and articles made of niobium.

[6]The published price for columbite ore was discontinued in 2001 at a range of $5.50 to $7.00 per pound of Nb_2O_5 content. The published prices of Brazilian and Canadian pyrochlore were discontinued in 1981 and 1989, respectively. Price is time-weighted average as reported in trade journals.

[7]Standard (steelmaking) grade. American Metal Market discontinued reporting the price of vacuum-grade ferroniobium in 2002 and standard grade in 2005.

[8]Mass-weighted average value of imported plus exported materials.

TABLE 2

SALIENT TANTALUM STATISTICS

		2005	2006	2007	2008	2009 [e]
United States:						
Government stockpile releases,[1] Ta content[2]	metric tons	210	289	--	--	--
Exports:						
Tantalum ores and concentrates,[3] Ta content	do.	174	247	146	96	94
Tantalum metal, gross weight	do.	567	590	207	390	138
Tantalum and tantalum alloy powder, gross weight	do.	242	112	158	176	94
Imports for consumption:						
Mineral ores and concentrates, Ta content	do.	382	322	294	357	109
Tantalum metal and tantalum-bearing alloys,[4] gross weight	do.	1,240	835	861	934	689
Tin slag	do.	NA	NA	NA	NA	NA
Reported consumption, raw materials Ta content	do.	W	W	W	W	W
Apparent consumption, Ta content	do.	852	498	644	629	473
Price, tantalite,[5] Ta_2O_5 content	dollars per kilogram	77	72	80	87	60
Value,[6] tantalum ores and concentrates, gross weight	do.	31	33	43	49	38
World, production of niobium-tantalum concentrates, Ta content	metric tons	1,380 [r]	867 [r]	994 [r]	1,190 [r]	665

See footnotes at end of table.

TABLE 2—Continued
SALIENT TANTALUM STATISTICS

[e]Estimated. do. Ditto. NA Not available. W Withheld to avoid disclosing company proprietary data. -- Zero.
[1]Release is the decrease in uncommitted inventory relative to the previous calendar year.
[2]To estimate Ta content, it was assumed that natural niobium and synthetic niobium-tantalum ores and concentrates are 32% Ta_2O_5; tantalum ores and concentrates are 37% Ta_2O_5; and Ta_2O_5 is 81.9% tantalum.
[3]Includes natural and synthetic tantalum ore and concentrates.
[4]Includes unwrought powders, unwrought alloys and metals, waste and scrap, and wrought alloys and metal.
[5]Time-weighted average price per Ta_2O_5 content as reported in trade journals. Includes Platts Metals Week and Ryan's Notes.
[6]Mass-weighted average value of imported plus exported materials.

TABLE 3
REPORTED CONSUMPTION, BY END USE, INDUSTRY STOCKS OF FERRONIOBIUM AND NICKEL NIOBIUM AND GOVERNMENT STOCKS BY MATERIAL IN THE UNITED STATES[1]

(Metric tons of niobium and tantalum content)

	2008	2009
End use:		
Steel:		
Carbon	1,450	970
Stainless and heat-resisting	674	551
Full alloy	(2)	(2)
High-strength low-alloy	852	651
Electric	(2)	(2)
Tool	(2)	(2)
Unspecified	1,010 [r]	1,030
Total	3,990 [r]	3,200
Superalloys	1,380 [r]	1,130
Alloys (excluding steels and superalloys)	16	21
Miscellaneous and unspecified	--	--
Grand total	5,380 [r]	4,350
Stocks, December 31:		
Consumer	341 [r]	321
Producer[3]	W	W
Total	341 [r]	321
National Defense Stockpile, total uncommitted inventory by material:		
Niobium metal ingots	10.0	10.0
Tantalum carbide powder	1.72	1.72

[r]Revised. W Withheld to avoid disclosing company proprietary; data not included in total. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Included with "Steel, unspecified."
[3]Ferroniobium only.

TABLE 4

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

HTS code[2]	Class	2008 Gross mass (kilograms)	2008 Value (thousands)	2009 Gross mass (kilograms)	2009 Value (thousands)	Principal destinations and sources in 2009 (gross mass in kilograms and values in thousand dollars)
	Exports:					
	Niobium:					
2615.90.6030	Ores and concentrates	62,800	$2,010	17,000	$954	Sweden 11,400, $778; Argentina 2,140, $104; United Kingdom 1,960, $42; Austria 778, $5; Italy 399, $3; Canada 308, $15; China 2, $6.
7202.93.0000	Ferroniobium	1,130,000	12,500	240,000	2,740	Mexico 127,000, $1,400; Canada 98,200, $1,180; Republic of Korea, 12,700, $140; Philippines 1,150, $15; New Zealand 200, $4.
	Tantalum:					
2615.90.3000	Synthetic concentrates	110,000	302	158,000	796	China 119,000, $436; Brazil 19,400, $56; Ireland 17,800, $277; United Kingdom 1,090, $10; France 811, $7; Switzerland 24, $10.
2615.90.6060	Ores and concentrates	167,000	2,490	160,000	2,110	Brazil 109,000, $524; Japan 32,900, $1,270; China 15,900, $219; United Kingdom 1,650, $80; France 283, $6; Costa Rica 9, $4.
8103.20.0030	Unwrought, powders	176,000	64,600	93,800	40,200	Mexico 42,600, $17,600; Germany 25,900, $14,100; Israel 19,500, $6,240; Sweden 2,200, $347; Japan 1,280, $755; Portugal 1,230, $704; Austria 419, $77; Thailand 272, $106; China 205, $89; Czech Republic 96, $51; Singapore 27, $14; Italy 10, $3; United Kingdom 5, $7; Norway 4, $19.
8103.20.0090	Unwrought, alloys and metal	39,000	4,390	6,760	1,030	Malaysia 3,620, $615; Germany 1,400, $5; United Kingdom 1,060, $181; Canada 620, $144; Singapore 37, $16; China 12, $6; Italy 11, $4; Republic of Korea, 4, $5; France 2, $3.
8103.30.0000	Waste and scrap	247,000	20,800	79,000	8,930	United Kingdom 18,700, $2,520; China 13,000, $1,130; Netherlands 10,000, $1,180; Estonia 8,100, $990; Hong Kong 6,710, $458; Australia 4,480, $879; Kazakhstan 4,280, $267; Germany 3,900, $419; Austria 3,770, $412; Canada 2,460, $208; Malaysia 1,570, $327; Thailand 1,000, $69; Republic of Korea, 571, $50.
8103.90.0000	Wrought	104,000	49,300	52,200	26,900	Mexico 19,900, $10,700; Japan 11,800, $4,690; Germany 9,470, $4,430; France 2,670, $1,260; United Kingdom 2,070, $1,030; Republic of Korea, 1,360, $1,370; Czech Republic 1,050, $716; Israel 826, $725; Malaysia 627, $363; Italy 589, $332; Taiwan 514, $169; Canada 404, $202; China 258, $328; Switzerland 214, $158.
	Total	XX	156,000	XX	83,600	
	Imports for consumption:					
	Niobium:					
2615.90.6030	Ores and concentrates	15,600	$87	4,960	$360	China 4,930, $357; Netherlands 33, $4.
2825.90.1500	Oxide	1,220,000	31,300	1,060,000	29,000	Brazil 909,000, $23,200; China 57,700, $2,320; Germany 50,000, $2,650; Russia 45,000, $801; United Kingdom 23, $9.

See footnotes at end of table.

TABLE 4—Continued

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

HTS code[2]	Class	2008 Gross mass (kilograms)	2008 Value (thousands)	2009 Gross mass (kilograms)	2009 Value (thousands)	Principal destinations and sources in 2009 (gross mass in kilograms and values in thousand dollars)
	Imports for consumption—Continued:					
	Niobium—Continued:					
	Ferroniobium:					
7202.93.4000	Silicon < 0.4%	258,000	8,290	151,000	5,080	Brazil 137,000, $4,560; Germany 12,100, $453; United Kingdom 2,040, $65.
7202.93.8000	Other	10,700,000	237,000	4,340,000	104,000	Brazil 2,950,000, $70,300; Canada 1,380,000, $33,400; Germany 1,500, $41.
	Total	11,000,000	245,000	4,490,000	109,000	
8112.92.4000	Unwrought, and powder[3]	1,130,000	47,500	699,000	24,100	Brazil 638,000, $21,700; Germany 36,500, $1,100; Estonia 14,300, $778; Russia 7,350, $165; China 1,020, $192; Japan 894, $48; Thailand 394, $79; Austria 75, $14; Hong Kong 43, $5.
	Tantalum:					
2615.90.3000	Synthetic concentrates	3,620	21	546	27	All From China.
2615.90.6060	Ores and concentrates	1,160,000	63,100	356,000	13,500	Mozambique 174,000, $5,470; Canada 116,000, $4,760; Australia 65,000, $3,260; China 855, $55,600; United Kingdom 23, $4.
8103.20.0030	Unwrought powders	230,000	52,800	139,000	39,500	China 73,600, $16,600; Japan 40,300, $16,100; Germany 19,400, $4,880; Thailand 3,140, $1,040; Kazakshtan 1,980, $410; Portugal 1,020, $408; Georgia 50, $11; Mexico 25, $9; Netherlands 5, $2.
8103.20.0090	Unwrought, alloys and metal	194,000	34,600	138,000	29,600	Kazakhstan 88,200, $20,200; China 40,000, $7,490; Germany 9,650, $1,580; Japan 330, $54; Netherlands 244, $33; United Kingdom 61, $49; Liechtenstein 19, $36.
8103.30.0000	Waste and scrap	410,000	26,000	335,000	23,800	China 83,200, $2,770; Estonia 59,900, $10,700; Austria 50,600, $2,890; Japan 36,800, $1,880; Portugal 32,100, $1,190; Germany 22,500, $437; France 11,800, $151; Hong Kong 11,500, $702; United Kingdom 7,530, $1,150.
8103.90.0000	Wrought	101,000	23,200	75,600	20,800	China 63,000, $14,700; Kazakhstan 5,750, $1,440; Austria 3,300, $2,200; Germany 2,130, $1,680; France 589, $150; Switzerland 230, $16; Denmark 206, $130; Singapore 134, $14; Japan 81, $228.
	Total	XX	524,000	XX	289,000	

XX Not applicable. -- Zero.

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

[2]Harmonized Tariff Schedule of the United States.

[3]Niobium waste and scrap is included in 8112.92.0600 along with other materials. Niobium other than unwrought; waste and scrap; and powders are included in 8112.99.9000 along with other materials.

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

TABLE 5
U.S IMPORTS FOR CONSUMPTION OF TANTALUM ORES AND CONCENTRATES, BY COUNTRY[1]

Country	2008		2009	
	Gross mass (kilograms)	Value (thousands)	Gross mass (kilograms)	Value (thousands)
Australia	774,000	$49,900	65,000	$3,260
Canada	193,000	7,340	116,000	4,760
China	9,900	653	855	56
France	64	3	--	--
Mozambique	179,000	5,000	174,000	5,470
Nigeria	6,110	206	--	--
United Kingdom	--	--	23	4
Total	1,160,000	63,100	356,000	13,500

-- Zero.

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

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

TABLE 6
NIOBIUM AND TANTALUM: WORLD PRODUCTION OF MINERAL CONCENTRATES, BY COUNTRY[1, 2]

(Metric tons)

Country[5]	Gross mass[3]					Niobium content[4]					Tantalum content[4]				
	2005	2006	2007	2008	2009[e]	2005	2006	2007	2008	2009[e]	2005	2006	2007	2008	2009[e]
Australia, columbite-tantalite[6]	3,820 [e]	2,140 [e]	1,630 [e]	2,060 [e]	318	--	--	--	--	--	854	478	441	557	81 [7]
Brazil:															
Nb minerals[8, 9]	247,023	206,550	245,766	246,000	247,000 [p]	39,162	48,129	57,267	58,000 [e]	58,000	--	--	--	--	--
Ta minerals[e, 6, 10]	792	645	650	650	650	--	--	--	--	--	216 [7]	176 [7]	180	180	180
Burundi	43	16	52	84 [r]	84	8	3	10 [r]	16 [r]	16	9	3	9	16 [r]	16
Canada:															
Nb minerals[9]	11,100 [e]	12,500 [e]	12,900 [e]	13,150	12,900	3,710	4,157	4,337	4,383	4,330 [7]	--	--	--	--	--
Ta minerals[6, 10]	282	249	201	150	110	--	--	--	--	--	63	56	45	40	25
Congo, (Kinshasa):															
Columbite-tantalite[e, 11]	124 [7]	52 [7]	267 [7]	380	330	28	12	61	86	75	33	14	71	100	87
Nb minerals	--	--	--	240 [e]	180	--	--	--	120 [e]	90	--	--	--	--	--
Ethiopia, tantalite	93	109	117 [r]	83 [r]	83	9	11	12	8 [r]	8	49 [r]	57 [r]	52 [r]	37 [r]	37
Mozambique[e]	281 [7]	95 [r, 7]	196	396 [r, 7]	405 [7]	20 [r]	7 [r]	14 [r]	28 [r]	29	81	27 [r]	56 [r]	110 [r]	113
Nigeria, columbite-tantalite[e]	110	900	450	500	450	45 [7]	387 [7]	180 [7]	194 [7]	180	5	10	20	25	20
Rwanda	276	188	490	490	430	87 [r]	59 [r]	150 [r]	150 [7]	130	68 [r]	46 [r]	120 [r]	120 [r]	104
Somalia[12]	--	--	--	11 [e]	7	--	--	--	2 [e]	2	--	--	--	3 [e]	2
Uganda[e]	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)
Zimbabwe[e]	--	NA	--	--	--	--	--	--	--	--	--	NA	--	--	--
Total	264,000	223,000	263,000	264,000	263,000	43,100	52,800	62,000	63,000	62,900	1,380	870 [r]	872 [r]	1,190 [r]	670

[e]Estimated. [p]Preliminary. [r]Revised. 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 niobium and tantalum contained in tin ores and slags. Table includes data available through July 5, 2010.

[3]Gross mass is mass of concentrate before metal is extracted.

[4]Content is mass of metal produced. Nb_2O_5 is 69.904% niobium; Ta_2O_5 is 81.897% tantalum.

[5]In addition to the countries listed, Bolivia, China, French Guiana, Kazakhstan, and Russia also produce, or are thought to produce, niobium and tantalum mineral concentrates, but available information is inadequate to make reliable estimates of output levels.

[6]Tantalum production reported in Ta_2O_5 converted to tantalum content. Gross mass is concentrate assumed to be one-third Ta_2O_5.

[7]Reported figure.

[8]Niobium concentrate production reported in Nb_2O_5 content converted to niobium content. Gross mass is concentrate assumed to be one-third Nb_2O_5.

[9]Includes columbite and pyrochlore.

[10]Includes djalmaite and tantalite.

[11]Reported data includes the North and South Kivu Provinces.

[12]From August 2008 to April 2009, 18 metric tons of columbite-tantalite were reportedly produced in Somalia. It is unclear if production continued after early April 2009.

[13]Less than ½ unit.

TABLE 7

FERRONIOBIUM (FERROCOLUMBIUM): WORLD PRODUCTION, BY COUNTRY[1]

(Metric tons, Nb content)

Country[2]	2005	2006	2007	2008	2009[e]
Brazil	25,621 [r]	27,434 [r]	34,612 [r]	25,403 [r]	25,410 [p, 3]
Canada	3,710	4,157 [r]	4,337	4,385	3,960
India[e]	-- [r]	-- [r]	-- [r]	-- [r]	--
Russia[e]	--	--	80	80	79
United States	NA	NA	NA	NA	NA
Total	29,300 [r]	31,600 [r]	39,000 [r]	29,900 [r]	29,400

[e]Estimated; estimated data are rounded to no more than three significant digits; may not add to totals shown. [p]Preliminary. [r]Revised. NA Not available. -- Zero.

[1]Table includes data available through August 20, 2010.

[2]In addition to the countries listed, Austria, China, and Germany are thought to have produced ferroniobium (ferrocolumbium), but production information is inadequate for the formulation of estimates of output levels.

[3]Reported figure.