



2010 Minerals Yearbook

NIOBIUM (COLUMBIUM) AND TANTALUM

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In 2010, U.S. niobium apparent consumption (measured in contained niobium) was 8,210 metric tons (t), 95% more than that of 2009; U.S. tantalum apparent consumption (measured in contained tantalum) was 1,160 t, 145% more than that of 2009. No domestic mine production of niobium or tantalum ore was reported.

Legislation and Government Programs

The Defense Logistics Agency, DLA Strategic Materials (formerly Defense National Stockpile Center) did not plan to dispose of niobium or tantalum materials under its fiscal year 2010 Annual Materials Plan (AMP) and to announced the fiscal 2011 plan. The DLA Strategic Materials did not sell niobium or tantalum materials in calendar year 2010. The DLA Strategic Materials' fiscal year 2011 AMP set maximum disposal goals for niobium and tantalum materials (niobium materials measured in contained niobium, and tantalum materials measured in contained tantalum) at zero (Defense Logistics Agency—Strategic Materials, 2011, p. 1). DLA Strategic Materials suspended the sale of niobium and tantalum materials to retain remaining quantities in the National Defense Stockpile inventory pending the outcome of the requirements review expected in January 2011 (Under Secretary of Defense for Acquisition, Technology and Logistics, 2011, p. 2).

Consumption

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 used 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

The annual average price (in dollars per kilogram of contained Ta_2O_5) of tantalite peaked in 2008 at \$96 and again in 2010 at \$120. The price peak in 2008 resulted from high demand especially from economic development in China. In 2010, the price peak took place as markets recovered from the world financial downturn and subsequent recession.

Foreign Trade

Niobium and tantalum material exports from and imports to the United States included ferroniobium; niobium chemicals,

metal, ore, and oxide; and tantalum metal and ore. In 2010, the values of foreign trade of these niobium and tantalum materials were \$122 million for exports (46% greater than that of 2009) and \$504 million for imports (74% greater than that of 2009).

The United States exported 281 t of niobium contained in niobium materials (44% greater than that of 2009) and imported 8,490 t of niobium contained in niobium materials (93% greater than that of 2009) (table 1). The United States exported 438 t of tantalum contained in tantalum materials (34% greater than that of 2009) and imported 1,600 t of tantalum contained in tantalum materials (100% greater than that of 2009) (table 2).

World Industry Structure

Based on a survey of its members, the Tantalum-Niobium International Study Center (TIC) reported annual niobium and tantalum raw material production (raw material production by members plus receipts of raw materials from nonmembers by producers and traders) to have been [in metric tons of contained tantalum (t-Ta)]—2005, 1,390 t-Ta; 2006, 948 t-Ta; 2007, 1,080 t-Ta; 2008, not available; and 2009, 489 t-Ta; and [in metric tons of contained niobium (t-Nb)]—2005, 44,400 t-Nb; 2006, 52,000 t-Nb; 2007, 69,500 t-Nb; 2008, 67,800 t-Nb; and 2009, 41,000 t-Nb. TIC aimed to resolve problems associated with the shipment of tantalum raw materials transported as Class 7 materials. Columbite ore, tantalite ore, and tin slag, as naturally occurring radioactive materials, are subject to national transportation regulations for such materials, which are usually based on United Nations regulations (Schwela, 2010a).

World Review

Burt and Millman (2010) described the scheme to break the linkage between mineral trade and conflict financing: effective and cost effective traceability from legitimate digger to exporter. They estimated that the Congo (Kinshasa) and Central Africa accounted for about 10% of the world's tantalum production in 2002–05. The TIC supported the ITRI Tin Supply Chain Initiative (iTSCi) pilot project that would bag and tag tantalum ore mined in Congo (Kinshasa) permitting its origin in the supply chain to be traced.

The geographic distribution of mineral production has increased for the past 150 years. Europe, along with the United States, accounted for nearly all world mineral production in the mid-19th century, but together now account for less than one-fifth of world mineral production. The world share of mineral production from the United States and Europe has been decreasing, while the share from Australia, Canada, China, the Commonwealth of Independent States, and several developing countries has been increasing. While exhaustion of resources

of any mineral or metal is not likely to take place, mineral scarcity will likely become an issue in coming decades. The displacement of Western countries by developing countries as the leading mineral producers has major geopolitical implications, because Europe is dependent on foreign supplies to satisfy its industrial demand. It is of concern that markets for scarce minerals could change from equal access competitive bidding markets to markets where trade is conducted under long-term supply agreements among large corporations with significant government involvement resulting in a marked political influence on mineral supply (Kooroshy and others, 2010, p. 42, 89–93).

To address its critical materials needs, the European Union (EU) developed a raw materials initiative comprised of monitoring critical materials, including niobium and tantalum, pursuing fair and sustainable supply from global markets, fostering sustainable supply from within the EU, and boosting resource efficiency and promoting recycling (European Commission, 2011, p. 143–147, 188–193).

The European Commission (EC) identified 41 raw materials and metals (relative to other materials and metals) critical to the EU based on the geopolitical framework in which they are produced and consumed. The EC based criticality on importance to the EU economy and supply risk. Supply risk was based on environmental risk, concentration of production, recycling, and substitution. The EC was concerned that there would be inadequate supply to meet emerging-technology demand. Niobium was determined to be of high economic importance, high supply risk, and high environmental country risk. Tantalum was determined to be of high economic importance and supply risk, and low environmental country risk. Concentration of production [niobium in Brazil, tantalum in Congo (Kinshasa)] was identified as the leading contributing factor to supply risk for niobium and tantalum. The emerging technology affecting demand for tantalum was identified as microcapacitors and medical technology. The emerging technology affecting demand for niobium was identified as microcapacitors and ferroalloys. In addition to increasing demand resulting from the emerging technologies identified above, raw material and metal demand will increase as the world economy grows. China's economy was growing as was that of India, and there remain large areas of the world, like Africa, where gross domestic product is substantially less than that of other areas, like Europe, providing possibilities for future economic growth. During the past 20 years, the world economy grew at 3.8% per year until 2004 and then at 5% per year, mainly as a result of China's economic growth. Assuming growth of 3.8% per year, raw material demand in 2030 was estimated to be 2.4 times that of 2006. The EC recommended periodic critical raw material assessments; improvement of raw materials statistical information; EU policies that improved access to primary raw materials resources including land access, trade, and investment; encouraging recycling; substitution; and efficient use (European Commission, 2010a, p. 143–147 (Nb), p. 188–193; b, p. 5, 6, 12–14, 19, 23, 34–39, 43, 47).

Australia.—The government of Western Australia reported that tantalite production data were not available in 2010; 105 t of contained tantalum pentoxide (Ta_2O_5) was produced in 2009

(Government of Western Australia, Department of Mines and Petroleum, 2011, p. 21). Australia reported that, as of December 31, 2009, 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 were 19,000 t of contained tantalum, and accessible economic-demonstrated resources for niobium were 115,000 t and for tantalum were 51,000 t (Geoscience Australia, 2010, p. 5–6).

Global Advanced Metals, formerly Talison Tantalum Ltd., operated the Wodgina and Greenbushes tantalum mines and mineral processing plants, which remained on care-and-maintenance status since December 2008 (Schwela, 2010b, p. 2). Global Advanced Metals planned to restart tantalum production when global inventory of tantalum is balanced (Global Advanced Metals, 2010).

Galaxy Resources Ltd. planned to ship tantalum concentrate from Mount Cattlin, Western Australia, near the town of Ravensthorpe, to Global Advanced Metals Pty. Ltd., starting in 2011 at the rate of 90,000 kg of contained Ta_2O_5 per year for the next 5 years (Galaxy Resources Ltd., 2010b, p. 8, 10). Galaxy reported proved reserves of 2.683 Mt containing 135 parts per million (ppm) Ta_2O_5 and probable reserves of 8.684 Mt containing 151 ppm Ta_2O_5 at a cutoff grade of 0.4% LiO_2 as of March 31, 2010 (Galaxy Resources Ltd., 2010a, p. 7).

Alkane Resources LTD's (2011, p. 5–8) (Dubbo Zirconia Project, Toongi deposit, New South Wales), Artemis Resources Ltd. (2010, p. 10) (Buchanan's Creek/Grant's Gully tenements south of Georgetown, Queensland), Capital Mining Ltd. (2011, p. 20–21) (Narraburra prospect about 12 kilometers (km) northeast of Temora, New South Wales) explored for niobium and (or) tantalum.

Brazil.—The National Department of Mineral Production (DNPM) reported that Anglo American Brazil Ltd. (a subsidiary of Anglo American plc) and Companhia Brasileira de Metalurgia e Mineração (CBMM) produced niobium, and Mineração Taboca produced tantalum. Pereira (2011) reported Brazilian niobium mine production of 165,723 t- Nb_2O_5 (tons of contained niobium pentoxide) from reserves of 4,499,106 t- Nb_2O_5 in 2009, from which Brazil produced 88,920 t- Nb_2O_5 contained in concentrate, 34,746 t-Nb contained in ferroniobium, and 2,333 t- Nb_2O_5 . Pontes (2011) reported Brazilian tantalum mine production of 218 t- Ta_2O_5 (tons of contained tantalum pentoxide) contained in concentrate from reserves of 87,782 t- Ta_2O_5 in 2009.

Anglo American Brazil Ltd. (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. Anglo reported that Catalão mined 1,209,400 t of ore and processed 909,300 t of ore containing 6.6 kilograms of niobium per metric ton of ore to produce 4,000 t of contained niobium in 2010. JORC-compliant proved and probable reserves in 2010 were 5.1 Mt at 1.07% Nb_2O_5 containing 55,000 t of niobium (Anglo American plc, 2011, p. 191, 198).

CBMM mined niobium ore from the Barreiro carbonatite complex (19°40' S, 46°57' W) 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% Nb₂O₅ 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 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).

Cia. Estanho Minas Brasil (Mibra) owned by Companhia Industrial Fluminense (CIF), an AMG Advanced Metallurgical Group N.V. company, was the leading world producer of tantalum, with an annual production capacity of 136 t of Ta₂O₅ contained in concentrate at Volta Grande Mine (21°05' S, 44°35' W). Mibra planned to increase production capacity to 227 t/yr of Ta₂O₅ contained in concentrate. CIF reported NI 43–101-compliant reserves of 6.32 Mt of compact pegmatite grading 375 g/t Ta₂O₅ and 92 g/t Nb₂O₅ in 2008 (Schwela, 2010b, p. 2–6).

Mineração Taboca S.A. mined columbite at the Pitinga Mine (0°47'01" N, 60°04'43" W). Taboca produced a ferroniobium-tantalum alloy containing 45% niobium, 4.5% tantalum, and 25% iron that was sold for niobium and tantalum oxide production (Mineração Taboca S/A, undated a, b).

Canada.—Canada reported niobium mine production of 4,419 t of contained Nb₂O₅ and no tantalum mine production in 2010 compared with 4,169 t of contained Nb₂O₅ and 29 t of contained Ta₂O₅ in 2009. Niobium was produced in Quebec, and tantalum, in Manitoba (Natural Resources Canada, 2011a, b).

Avalon Rare Metals Inc. (Toronto, Ontario) prospected for niobium and tantalum at its Thor Lake (about 62°06'20" N, 112°36' W) property. Avalon completed a prefeasibility study and undertook a bankable feasibility study. Avalon reported Thor Lake probable reserves of 12.01 Mt at 0.41% Nb₂O₅ and 0.041% Ta₂O₅. Avalon planned to produce 1,700 t/yr of Nb₂O₅ and 100 t/yr of Ta₂O₅ (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), Carbo (northeast of Prince George, British Columbia), and Eldor (south of Kuujuaq, Quebec) properties that host carbonatite deposits. Commerce Resources reported NI 43–101-compliant Blue River (52°19' N, 119°10' W), comprising Fir, Verity, and Upper Fir deposits, indicated resources of 36.35 Mt containing 7,090 t of Ta₂O₅ and 61,650 t of Nb₂O₅ (Commerce Resources Corp., 2011, p. 4-1, 17-1–17-21).

IAMGOLD Corp. (Toronto, Ontario) mined niobium contained in pyrochlore mineral from the Saint-Honoré carbonatite deposit at the Niobec Mine (about 48°32' N, 71°09' W). Niobec mill production capacity was 4,500 t/yr of niobium. The mill produced concentrate from which Niobec produced Nb₂O₅ that was then converted to standard grade (66% niobium) ferroniobium by aluminothermic reduction. IAMGOLD completed a paste backfill plant and mill expansion. IAMGOLD reported that niobium mine production in 2010 was 4,400 t of contained Nb compared with 4,100 t in 2009 and 4,400 t in 2008. IAMGOLD reported 45.716 Mt of proven plus probable

ore reserves containing 243,800 t of Nb₂O₅ (average ore grade of 0.53% Nb₂O₅). In 2010, IAMGOLD mined 1.792 Mt of ore, milled 1.864 Mt of ore, and produced 4,400 t of Nb at the Niobec Mine (IAMGOLD Corp., 2011, p. 2, 16).

MDN Inc. (2011, p. 14) completed a feasibility study in March 2011 for its Crevier niobium project (49°30' N, 72°49' W). The Crevier project reported measured plus indicated resources of 25.369 Mt containing 0.196% Nb₂O₅ and 234 ppm Ta₂O₅. MDN planned to start Crevier Mine construction in 2013, with possible production of 4,000 metric tons per day from an open pit. MDN planned to use conventional flotation circuit to produce primary concentrate followed by niobium and tantalum oxide separation using acid leaching (Schwela, 2010b, p. 9).

Tantalum Mining Corp. of Canada Ltd. (50°26' N, 95°27' W) suspended mine production at its tantalite mine in Manitoba in April 2009 and operated on inventory through November (Cabot Corp., 2011, p. 6).

Niocan Inc. (2011, p. 2) explored for niobium minerals at its Oka property near Oka, Quebec. Niocan reported 10.63 Mt of measured plus indicated resources of 0.68% Nb₂O₅ as of December 2009.

Nuinsco Resources Ltd. (2011, p. 4) (Prairie Lake, Ontario), Quest Rare Minerals Ltd. (2011) (Misery Lake and Strange Lake, on the Quebec-Labrador border), Sarissa Resources Inc. (2010, p. 58) [Nemegosenda niobium property (48°00' N, 83°06' W), Ontario], and Taseko Mines Ltd. (2011, p. 5) (Aley prospect, British Columbia) explored for niobium minerals.

China.—The leading tantalum mining areas were at Yichun, Jiangxi Province, and Nanping, Fujian Province. TiChun Tantalum & Niobium Mine (27°38'58.10" N, 114°31'4.06" E) produced tantalum and niobium concentrate.

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 (coltan) deposits (Fetherston, 2004, p. 71). Shamika Resources Inc. (Montreal, Quebec, Canada) explored for tantalum and niobium through Shamika Congo Kalehe SPRL (Schwela, 2010b, p. 11). Katanga Province reported coltan mineral exports of 159.72 t in 2010. The leading exporter was Mining Mineral Resources Sprl (Kitumba, 2011).

Egypt.—Tantalum Egypt JSC [Gippsland Ltd. (Claremont, Australia) and the Government of Egypt] planned to mine tantalite from the Abu Dabbab (25°20'59.42" N, 34°13'30.07" E) and Nuweibi (25°12'3.09" N, 34°29'56.15" E) deposits, starting with Abu Dabbab in 2013 (Schwela, 2010b, p. 7). Gippsland reported proven reserves Abu Dabbab were 15.20 Mt at 260 g/t Ta₂O₅ and probable reserves 15.04 Mt at 250 g/t Ta₂O₅. H.C. Stark Group GmbH (Goslar, Germany) committed to buy 300,000 kilograms per year of contained Ta₂O₅ for the first 10 years of the mine operation (Gippsland Ltd., 2011, p. 8–9, 16).

Germany.—Germany, as an industrialized, economically developed nation, grew through technological innovation.

German industry relied on imported raw materials supply, which emerging technologies would convert into high-tech, cutting edge products. Wage cost increased more slowly than raw materials cost that accounted for 43% of manufacturing sector cost in 2006 (compared to 1.8% for energy, 22.7% for personnel, and 32.5% for other). Niobium and tantalum were among 15 vulnerable raw materials identified as needed by the German manufacturing industry as a result of the analysis of the impact of 32 emerging technologies. German economic development depends on secure supply of stably priced raw materials (Angerer 2009, p. 1, 2, 9–13).

Greenland.—Ram Resources Ltd. (Perth, Australia) explored the Motzfeldt area (near 61°15' N, 46° W). More exploration was required to define JORC-compliant resources (Ram Resources Ltd., 2010a, p. 6; Schwela, 2010b, p. 10).

Malawi.—Globe Metals & Mining Ltd. (Australia) planned to bring the Kanyika joint-venture niobium mining project with tantalum and uranium byproducts into production in 2013. Globe planned to produce about 3,000 t/yr of ferroniobium and 192 t/yr of Ta₂O₅. Globe planned to extract oxides of niobium, tantalum, and uranium via solvent extraction and to make ferroniobium from the Nb₂O₅ (Mining Journal, 2010, p. 8). Globe reported updated JORC-compliant (measured plus indicated plus inferred) resources for the Kanyika niobium project (about 12°38' S, 33°38' E) of 60 Mt containing 174,000 t of Nb₂O₅ (0.29% average grade) and 8,400 t of Ta₂O₅ (0.014% average grade), at a cutoff grade of 0.15% Nb₂O₅. Globe planned to prepare a preliminary mine design (Globe Metals & Mining Ltd., 2010, p. 4–8).

Mozambique.—Noventa Ltd. (St. Helier, United Kingdom) stopped production at the Marropino Mine (16°30' 40" S, 37°54' 10" E) in January and planned to restart production in 2011 and upgrade its processing plant. Noventa planned to produce about 300 t/yr Ta₂O₅ contained in concentrate (Schwela, 2010b, p. 2; Noventa Ltd., 2011, p. 6, 9).

Pacific Wildcat Resources Corp. (Canada), a mineral exploration company, acquired Tantalum Mineracao e Prospeccas Ltda., which held licenses for tantalum exploration in the Alto Lingonha belt, Zambezi Province (about 15°45'10" S, 33°15'10" E) near the Muiane Mine, a historical tantalum producer. Pacific also purchased a tantalum treatment plant, which it started to commission and planned to use to conduct metallurgical test work (Pacific Wildcat Resources Corp., 2011, p. 3).

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. However, there had been no change to the status of its license (Tertiary Minerals plc, 2010, p. 3, 8).

Current research and technology.—Fife (2010) described how tantalum and other elements heavier than iron are made when heavy stars (stars with mass greater than the Chandrasekhar limit) collapse, resulting in a supernova explosion that disperses many heavy elements and leaves a neutron star.

Peries (2010, p. 8–9) reported that niobium is a potential short-term substitute for vanadium in high-strength low-alloy steel (HSLA). Like vanadium, niobium is used to increase

the yield strength of steel, albeit by a different physical process. Vanadium and niobium provide grain refinement and precipitation hardening; however, they affect other metallurgical characteristics differently. Historical performance suggested that niobium could substitute for about 20% to 25% of vanadium used in HSLA steel.

Niobium contributes to solid solution strengthening, strengthening through carbide formation, and to precipitation hardening in nickel-based superalloys such as alloys 625, 706, and 718 (Patel and Smith, undated).

Gilman (2010) reported that tantalum is used in sputtering targets to make thin films on integrated circuits. Tantalum forms a protective oxide that is the basis for its application in electrolytic capacitors. In thermal ink-jet printer heads, a tantalum anticavitation film is used to protect the device from the ink. In integrated circuits that use copper metallization, a thin film of tantalum and tantalum nitride is formed to chemically isolate the copper. Copper metallization is also used in flat panel liquid crystal display panels.

Gillesberg and Gambale (2010) reported that a thin layer of tantalum metal alloy extended the operating life of many parts in the highly chemically aggressive conditions found in the sulfur-iodine water-splitting cycle, a leading candidate for thermochemical hydrogen production.

Freeman and others (2010) compared the alternating and direct current characteristics of recently developed polymer tantalum capacitors with those of traditional wet tantalum capacitors. The historical development of tantalum capacitor anodes has been from wet anodes to manganese oxide anodes to various polymer anodes. The new polymer characterized by Freeman reversed the trend of decreasing operating voltage while retaining low equivalent series resistance and high volumetric efficiency.

Shlyakhov and others (2010) described the production of niobium-titanium and niobium-tin alloy for use in superconducting magnets. The magnets were for use in the International Thermonuclear Experimental Reactor, an internationally sponsored tokamak nuclear fusion reactor.

Outlook

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 automobile, construction, and pipeline industries. Greater demand for

natural gas was expected to result in increased demand for pipeline steel. The sharp fall 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 ton of steel produced was 55 to 60 g/t, and that of highly economically developed countries was 100 g/t and that of China was 40 g/t, suggesting significant potential for niobium consumption growth as the Chinese economy continues to develop (Roskill Information Services Ltd., 2009a, p. 124–125).

Tantalum.—Consumers relied heavily on tantalum inventories and large quantities of highly contentious and politically sensitive, low-cost columbite-tantalite from Congo (Kinshasa) that appeared to have displaced producers in the conventional supply chain, while an estimated 40% of tantalum mine production capacity 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-tantalite from the supply chain. It was thought that a ban on such material by the United States and the EU 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 the 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 and demand exceeding mine production capacity development, Zogbi (2010) estimated 2009 world tantalum mine production capacity, excluding Australia and Mozambique, to have been 727 t/yr of tantalum (equivalent to 845 t/yr of Ta₂O₅, 1,031 t/yr of tantalite) and recycling production to be 544 t/yr of tantalum (equivalent to 633 t/yr of Ta₂O₅, 772 t/yr of tantalite). Australian production capacity was estimated to be 854 t/yr of tantalum (equivalent to 993 t/yr of Ta₂O₅, 1,211 t/yr of tantalite) (Talison Minerals Pty. Ltd., 2007). Mozambique production capacity was estimated to be 83 t/yr of tantalum (equivalent to 96 t/yr of Ta₂O₅, 117 t/yr of tantalite) (Noventa Ltd., 2010, p. 12). Based on these estimates, 2009 world tantalum production capacity was 3,589 t/yr tantalum while projected 2009 demand was 2,460 t of tantalum based on 4% annual growth rate from 2006—enough production capacity to meet demand even with Australian production closed. World 2013 projected demand was 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 STATISTICS¹

		2006	2007	2008	2009	2010 ^c
United States:						
Government stockpile releases, Nb content ^{2,3}	metric tons	156	--	--	--	--
Exports, Nb content ⁴	do.	561	1,101	781	195	281
Imports for consumption:						
Mineral concentrates, Nb content	do.	120	109	134	41	5
Niobium metal, gross weight ⁵	do.	1,450	864	1,130	699	1,380
Niobium oxide, Nb content ^c	do.	760	744	852	742	824
Ferroniobium, Nb content ^c	do.	8,150	8,400	7,120	2,920	6,280
Reported consumption, Nb content						
Raw materials	do.	W	W	W	W	W
Ferroniobium and nickel niobium ^c	do.	5,050	6,510	5,380	4,350	5,590
Apparent consumption, Nb content	do.	10,100	9,020	8,450	4,210	8,210
Value: ⁶						
Niobium ores and concentrates (gross weight)	dollars per kilogram	13.71	22.55	26.70	59.86	19.84
Niobium oxide (gross weight)	do.	14.07	17.64	25.65	27.30	30.32
Ferroniobium (gross weight)	do.	9.13	13.88	21.29	23.59	24.01
World, production of niobium-tantalum concentrates, Nb content	metric tons	52,800	62,000	63,000	62,800 ^r	62,900

^cEstimated. ^rRevised. do. Ditto. W Withheld to avoid disclosing company proprietary data. -- Zero.

¹Data are rounded to no more than three significant digits, except values.

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

³To estimate Nb content, it was assumed that natural tantalum and synthetic tantalum-niobium ores and concentrates are 16% niobium pentoxide (Nb₂O₅); niobium ores and concentrates are 30% Nb₂O₅; and Nb₂O₅ is 69.9% Nb.

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

⁵Includes niobium and articles made of niobium.

⁶Mass-weighted average value of imported plus exported materials.

TABLE 2
SALIENT TANTALUM STATISTICS¹

		2006	2007	2008	2009	2010 ^c
United States:						
Government stockpile releases, ² Ta content ³	metric tons	289	--	--	--	--
Exports:						
Tantalum ores and concentrates, ⁴ Ta content	do.	247	146	96	94	58
Tantalum metal, gross weight	do.	590	207	390	138	246
Tantalum and tantalum alloy powder, gross weight	do.	112	158	176	94	134
Imports for consumption:						
Mineral ores and concentrates, Ta content	do.	322	294	357	109	9
Tantalum metal and tantalum-bearing alloys, ⁵ gross weight	do.	835	861	934	689	1,590
Reported consumption, raw materials Ta content	do.	W	W	W	W	W
Apparent consumption, Ta content	do.	498	644	629	473	1,160
Price, tantalite, ⁶ Ta ₂ O ₅ content	dollars per kilogram	72	82 ^r	96 ^r	89 ^r	120
Value, ⁷ tantalum ores and concentrates, gross weight	do.	33	43	49	30 ^r	32
World, production of niobium-tantalum concentrates, Ta content	metric tons	859 ^r	995 ^r	1,270 ^r	764 ^r	682

^cEstimated. ^rRevised. do. Ditto. W Withheld to avoid disclosing company proprietary data. -- Zero.

¹Data are rounded to no more than three significant digits.

²Release is the decrease in uncommitted inventory relative to the previous calendar year.

³To estimate Ta content, it was assumed that natural niobium and synthetic niobium-tantalum ores and concentrates are 32% Ta₂O₅, tantalum ores and concentrates are 37% Ta₂O₅, and Ta₂O₅ is 81.9% tantalum.

⁴Includes natural and synthetic tantalum ore and concentrates.

⁵Includes unwrought powders, unwrought alloys and metals, waste and scrap, and wrought alloys and metal.

⁶Average annual price per Ta₂O₅ content as reported in Ryan's Notes.

⁷Mass-weighted average value of imported plus exported materials.

TABLE 3
 REPORTED CONSUMPTION, BY END USE, INDUSTRY STOCKS OF FERRONIUM AND
 NICKEL NIOBIUM AND GOVERNMENT STOCKS BY MATERIAL IN THE UNITED STATES¹

(Metric tons of niobium and tantalum content)

	2009	2010
End use:		
Steel:		
Carbon	970	1,630
Stainless and heat-resisting	551	727
Full alloy	(2)	(2)
High-strength low-alloy	651	739
Electric	(2)	(2)
Tool	(2)	(2)
Unspecified	1,030	1,070
Total	3,200	4,160
Superalloys	1,130	1,400
Alloys (excluding steels and superalloys)	21	24
Miscellaneous and unspecified	--	--
Grand total	<u>4,350</u>	<u>5,590</u>
Stocks, December 31:		
Consumer	322 ^r	813
Producer ³	W	W
Total	322 ^r	813
National Defense Stockpile, total uncommitted inventory by material:		
Niobium metal ingots	10.0	10.0
Tantalum carbide powder	1.72	1.72

^rRevised. W Withheld to avoid disclosing company proprietary data. -- Zero.

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

²Included with "Steel, unspecified."

³Ferroniobium only.

TABLE 4
U.S. FOREIGN TRADE IN NIOBIUM AND TANTALUM METAL AND ALLOYS, BY CLASS¹

HTS code ²	Class	2009		2010		Principal destinations and sources in 2010 (gross mass in kilograms and values in thousand dollars)
		Gross mass (kilograms)	Value (thousands)	Gross mass (kilograms)	Value (thousands)	
Exports:						
Niobium:						
2615.90.6030	Ores and concentrates	17,000	\$954	24,900	\$228	Germany 18,100, \$25; United Kingdom 4,960, \$78; India 1,700, \$115; China 33, \$6; Italy 31, \$4.
7202.93.0000	Ferriobium	240,000	2,740	395,000	4,190	Canada 371,000, \$3,930; Mexico 15,500, \$170; Philippines 4,530, \$50; Peru 2,770, \$30; Colombia 233, \$8.
Tantalum:						
2615.90.3000	Synthetic concentrates	158,000	796	22,800	214	South Africa 16,500, \$152; Ireland 4,910, \$48; United Kingdom 1,120, \$10; Japan 357, \$3.
2615.90.6060	Ores and concentrates	160,000	2,110	149,000	2,880	Brazil 72,300, \$487; Germany 32,100, \$1,000; China 18,600, \$78; Netherlands 17,200, \$462; Hong Kong 8,680, \$840; United Kingdom 48, \$8; Malaysia 25, \$9.
8103.20.0030	Unwrought, powders	93,800	40,200	134,000	57,400	Mexico 64,700, \$28,000; Germany 34,400, \$16,300; Israel 18,000, \$8,080; Austria 12,700, \$2,430; Portugal 2,050, \$1,130; Japan 1,120, \$834; China 806, \$442; Thailand 12, \$80; Malaysia 25, \$9.
8103.20.0090	Unwrought, alloys and metal	6,760	1,030	15,400	2,730	Germany 11,900, \$1,950; Malaysia 2,090, \$492; Taiwan 595, \$114; India 184, \$66; Mexico 175, \$8; Canada 57, \$11; Australia 27, \$8; Singapore 24, \$26; Japan 13, \$8; Republic of Korea 300, \$24; Italy 6, \$4; France 3, \$4; Brazil 1, \$4.
8103.30.0000	Waste and scrap	78,700 ^r	8,930	165,000	18,800	Hong Kong 64,440, \$6,080; United Kingdom 25,800, \$4,290; Japan 25,600, \$2,570; Germany 15,000, \$2,500; Kazakhstan 11,500, \$467; Austria 7,980, \$1,280; Canada 6,020, \$557; Brazil 3,670, \$415; Malaysia 2,840, \$339.
8103.90.0000	Wrought	52,200	26,900	65,200	35,900	Mexico 28,900, \$16,600; Germany 19,500, \$8,670; Japan 6,750, \$3,630; Republic of Korea 1,860, \$1,630; Czech Republic 1,160, \$844; Dominican Republic 1,080, \$644; United Kingdom 947, \$371; Malaysia 885, \$525; France 867, \$504; Israel 852, \$724; Canada 667, \$360; China 495, \$597; Thailand 291, \$173; Sweden 201, \$88.
Total		XX	83,600	XX	122,000	
Imports for consumption:						
Niobium:						
2615.90.6030	Ores and concentrates	4,960	360	11,600	494	China 9,430, \$471; Japan 2,130, \$23.
2825.90.1500	Oxide	1,060,000	29,000	1,180,000	35,800	Brazil 1,010,000, \$28,300; China 58,600, \$2,580; Russia 56,400, \$1,580; Germany 56,300, \$3,260; Japan 50, \$4.
7202.93.4000	Ferriobium:	151,000	5,080	444,000	14,900	Brazil 336,000, \$10,800; United Kingdom 80,400, \$2,760; Germany 28,400, \$1,280.
7202.93.8000	Silicon < 0.4%	4,340,000	104,000	9,210,000	222,000	Brazil 7,940,000, \$190,000; Canada 1,260,000, \$31,800; Germany 10,200, \$338; France 3, \$94.
	Other	4,490,000	109,000	9,660,000	237,000	
8112.92.4000	Total	699,000	24,100	1,380,000	56,900	Brazil 1,290,000, \$50,100; Estonia 45,700, \$3,770; Germany 35,000, \$1,940; Japan 5,090, \$255; China 4,230, \$685; Finland 144, \$213; Thailand 82, \$136; Hong Kong, 25, \$25; Austria 13, \$29.
	Unwrought powders ³					
Tantalum:						
2615.90.3000	Synthetic concentrates	546	27	--	--	XX.
2615.90.6060	Ores and concentrates	356,000	13,500	19,800	2,520	Brazil 11,000, \$2,150; Mozambique 8,350, \$270; China 255, \$88; Canada 255, \$5.
8103.20.0030	Unwrought powders	139,000	39,500	207,000	60,900	Thailand 73,400, \$20,400; China 64,000, \$18,700; Germany 39,300, \$9,160; Japan 28,400, \$12,000; Portugal 915, \$401; Georgia 378, \$153; United Kingdom 990, \$138; India 130, \$3; Mexico 35, \$14.
8103.20.0090	Unwrought, alloys and metal	138,000	29,600	193,000	36,800	Kazakhstan 73,800, \$12,600; China 49,800, \$12,000; Germany 23,300, \$4,580; Thailand 18,000, \$4,400; United Kingdom 12,340, \$1,620.
8103.30.0000	Waste and scrap	335,000	23,800	1,070,000	42,000	Russia 320,000, \$2,540; Germany 230,000, \$11,100; Mexico 141,000, \$6,840; Estonia 64,500, \$3,490; China 62,300, \$5,480; Israel 41,600, \$784; Taiwan 39,100, \$483; Japan 35,400, \$2,360; Austria 28,200, \$1,820; United Kingdom 24,900, \$2,400; Indonesia 15,000, \$105; Czech Republic 17,100, \$349; Singapore 9,880, \$782; Hong Kong 9,620, \$772; Kazakhstan 28,300, \$489; France 5,050, \$66; Austria 5,230, \$2,400; Italy 4,750, \$98; China 67,100, \$19,400; Kazakhstan 28,300, \$6,180; France 4,370, \$962; Germany 2,600, \$1,360; Republic of Korea, 2,260, \$331; Belgium 1,410, \$118; Israel 1,010, \$129; Hong Kong 394, \$47.
Total		XX	289,000	XX	504,000	

^rRevised. XX Not applicable. -- Zero.

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

²Harmonized Tariff Schedule of the United States.

TABLE 4—Continued
U.S. FOREIGN TRADE IN NIOBIUM AND TANTALUM METAL AND ALLOYS, BY CLASS¹

³Niobium waste and scrap is included in 8112.92.0600 along with other materials. Niobium other than unwrought; waste and scrap; and powders is 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 COUNTRY¹

Country	2009		2010	
	Gross mass (kilograms)	Value (thousands)	Gross mass (kilograms)	Value (thousands)
Australia	65,000	\$3,260	--	--
Brazil	--	--	11,000	\$2,150
Canada	116,000	4,760	255	5
China	855	56	255	88
Mozambique	174,000	5,470	8,350	270
United Kingdom	23	4	--	--
Total	356,000	13,500	19,800	2,520

--Zero.

¹Data 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				
	2006	2007	2008	2009	2010 ^e	2006	2007	2008	2009	2010 ^e	2006	2007	2008	2009	2010 ^e
Australia, columbite-tantalite ⁶	2,140 ^e	1,630 ^e	2,060 ^e	318 ⁷	--	--	--	--	--	--	478	441	557	81 ⁷	--
Brazil:															
Nb minerals ^{8,9}	206,550	245,766	246,000 ^e	247,000 ^e	245,000	48,129	57,267	58,000 ^e	58,000 ^e	58,000	--	--	--	--	--
Ta minerals ^{6,10}	645	650	650	650	650	--	--	--	--	--	176 ⁷	180	180	180	180
Burundi	16	52	84	84 ^e	84	3	10	16	16 ^e	16	3	9	16	16	16
Canada:															
Nb minerals ⁹	12,500 ^e	12,900 ^e	13,150	12,900	13,200	4,177 ^r	4,337	4,383	4,330	4,419 ⁷	--	--	--	--	--
Ta minerals ^{6,10}	249	201	150	110	--	--	--	--	--	--	56	45	40	25	--
Congo (Kinshasa):															
Columbite-tantalite ^{6,11}	52 ⁷	267 ⁷	509 ^{r,7}	490 ^{r,7}	510	12	61	120 ^r	110 ^r	120	14	71	140 ^r	130 ^r	140
Nb minerals	--	--	119 ^r	44 ^e	--	--	-- ^{r,e}	--	22 ^{r,e}	--	--	--	--	--	--
Ethiopia, tantalite	109	117	183 ^r	206 ^r	210	11	12	18 ^r	21 ^r	21	49 ^r	53 ^r	83 ^r	93 ^r	95
Mozambique ^e	95 ⁷	196 ⁷	396 ⁷	405 ⁷	430	7	14	28	29	30	27	56	110	113	120
Nigeria, columbite-tantalite ^e	900	450	500	450	450	387 ⁷	180 ⁷	194 ⁷	190 ^r	190	10	20	25	20	20
Rwanda	188	490	490 ^e	430 ^e	450	59	150	150	130	140	46	120	120 ^e	104 ^e	110
Somalia ^{e,12}	--	--	11	7	--	--	--	2	2	--	--	--	3	2	--
Uganda ^e	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)	(13)
Zimbabwe ^e	NA	--	--	--	--	--	--	--	--	--	NA	--	--	--	--
Total	223,000	263,000	264,000	263,000	261,000	52,800	62,000	63,000	62,800 ^r	62,900	859 ^r	995 ^r	1,270 ^r	764 ^r	682

^eEstimated. ^rRevised. NA Not available. -- Zero.

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

²Excludes production of columbium and tantalum contained in tin ores and slags. Table includes data available through July 5, 2011.

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

⁴Content is mass of metal produced. Nb₂O₅ is 69.904% niobium; Ta₂O₅ is 81.897% tantalum.

⁵In 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.

⁶Tantalum production reported in Ta₂O₅ converted to tantalum content. Gross mass is concentrate assumed to be one-third Ta₂O₅.

⁷Reported figure.

⁸Niobium concentrate production reported in Nb₂O₅, content converted to niobium content. Gross mass is concentrate assumed to be one-third Nb₂O₅.

⁹Includes columbite and pyrochlore.

¹⁰Includes djallmaite and tantalite.

¹¹Reported data includes the North and South Kivu Provinces.

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

¹³Less than ½ unit.

TABLE 7
 FERRONIUM (FERROCOLUMBIUM): WORLD PRODUCTION, BY COUNTRY¹

(Metric tons, Nb content)

Country ²	2006	2007	2008	2009 ^c	2010
Brazil	27,434	34,612	35,534	22,932 ³	23,100
Canada	4,157	4,337	4,385	4,620	4,620
Russia ^e	--	80	80	79	80
United States	NA	NA	NA	NA	NA
Total	31,600	39,000	40,000	27,600	27,800

^cEstimated; estimated data are rounded to no more than three significant digits; may not add to totals shown. ^fRevised. NA Not available. -- Zero.

¹Table includes data available through July 15, 2011.

²In 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.

³Reported figure.