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TITANIUM [ADVANCE RELEASE]

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TITANIUM

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World production of titanium dioxide (TiO_2) contained in titanium mineral concentrates was nearly unchanged compared with that of 2007. A slight decline in global production of ilmenite concentrates was somewhat offset by increased production of rutile concentrates. The United States continued to be heavily reliant on imports of titanium mineral concentrates from Australia, Canada, and South Africa.

In 2008, global consumption of TiO_2 pigment was estimated to be 4.7 million metric tons (Mt) with a sharp downturn in consumption during the last quarter (Mineral Sands Report, 2009). Global TiO_2 pigment production capacity was estimated to be 5.3 Mt. According to U.S. Geological Survey (USGS) survey data, domestic production of TiO_2 pigment decreased by 6% compared with that of 2007.

Consumption of titanium used in steel and others alloys decreased moderately because of the global economic recession that began in 2008. Existing orders for commercial aircraft and consumption for military applications buoyed the consumption of titanium metal. In 2008, domestic production of titanium ingot decreased slightly and mill product production increased by 4% compared with production in 2007.

Legislation and Government Programs

The Defense Advanced Research Projects Agency (DARPA) continued to fund work on low-cost extraction of titanium metal from oxide ores. DARPA efforts were aimed at producing high-quality titanium at target costs of less than $8.81 per kilogram. In fiscal year (FY) 2008, the initiative achieved the goal of producing 110 kilograms per day (kg/d) of titanium metal. In FY 2009, DARPA hoped to produce up to 1,100 kg/d and verify the cost of production was less than the target cost. In FY 2010, DARPA planned to demonstrate consolidation of titanium powder without using conventional melting techniques (Defense Advanced Research Projects Agency, 2009, p. 183).

Production

Mineral Concentrates.—Titanium mineral concentrates of economic importance include ilmenite, leucoxene, rutile, synthetic rutile, and titaniferous slag. Mining of titanium minerals is usually performed using surface methods. Dredging and dry mining techniques are used for the recovery of heavy minerals. Gravity spirals are used to separate the heavy-mineral suite, while magnetic and high-tension separation circuits are used to separate the heavy-mineral constituents. Ilmenite is often processed to produce a synthetic rutile or titaniferous slag. Although numerous technologies are used to produce synthetic rutile, nearly all are based on either selective leaching or thermal reduction of iron and other impurities in ilmenite. Titaniferous slag with a TiO_2 content of 75% to 95% is produced commercially using pyrometallurgical processes.

U.S. mineral concentrate producers were DuPont Titanium Technologies [a subsidiary of E.I. du Pont de Nemours and Co. (DuPont)] and Iluka Resources, Inc. (a subsidiary of Iluka Resources Ltd.). DuPont's mining operations near Starke, FL, produced a mixed product containing ilmenite, leucoxene, and rutile that was used as a feedstock in DuPont's TiO_2 pigment plants. In 2008, Iluka produced titanium mineral concentrates from its heavy-mineral sand operations at Stony Creek, VA.

In Virginia, Iluka was in the process of developing the Brink deposit to support the continued operation of its Stony Creek mining operations. The Brink deposit is about 48 kilometers (km) south of the Stony Creek mining operations. During its mine life, the Brink deposit was expected to produce 792,000 metric tons (t) of ilmenite and extend the economic life of the Stony Creek operations to 2015 (Iluka Resources Ltd., 2009a, p. 11).

Metal.—Commercial production of titanium metal involves the chlorination of titanium-containing mineral concentrates to produce titanium tetrachloride ($TiCl_4$), which is reduced with magnesium (Kroll process) or sodium (Hunter process) to form a commercially pure form of titanium metal. As the metal is formed, it has a porous appearance and is referred to as sponge. Titanium ingot and slab are produced by melting titanium sponge or scrap or a combination of both, usually with various other alloying elements, such as aluminum and vanadium. Electron beam (EB), plasma arc melt (PAM), scull, and vacuum-arc remelting (VAR) are the commercial methods used to produce ingot and slab. Titanium mill products are produced from the drawing, forging, and rolling of titanium into products of various sizes and shapes. These mill products include billet, pipe and tube, plate, rod and bar, sheet, strip, and wire. Titanium castings are produced by investment casting and rammed graphite mold casting. Ferrotitanium is usually produced by induction melting of titanium scrap with iron or steel, but may be produced through the aluminothermic reduction of ilmenite. The two standard grades of ferrotitanium that are normally produced contain 40% and 70% titanium. Domestic ferrotitanium capacity was estimated to be 17,300 metric tons per year (t/yr).

In 2008, U.S. producers of titanium sponge were Allegheny Technologies Inc. (ATI), Honeywell Electronic Materials Inc., and Titanium Metals Corp. (Timet). ATI's Albany, OR, plant and Timet's Henderson, NV, plant produced titanium sponge using the Kroll process. Honeywell Electronic Materials' plant in Salt Lake City, UT, produced titanium sponge using the Hunter process and supported the company's production of electronic-grade titanium. Data on domestic production of

titanium sponge were withheld to avoid disclosing company proprietary data (table 2).

ATI expanded its Albany, OR, facility by raising sponge capacity to 9,980 t/yr from 7,260 t/yr. ATI's new 10,900-ton-per-year titanium sponge plant adjacent to U.S. Magnesium LLC's magnesium plant in Rowley, UT, was expected to be commissioned in 2009. When fully operational, ATI's sponge capacity was projected to reach 20,900 t/yr. ATI expanded its titanium ingot capacity through the expansion of its EB furnace and the addition of new PAM and VAR furnaces (Allegheny Technologies, Inc., 2009, p. 58). ATI did not publish its titanium ingot capacity; however, based on previously reported expansion plans, capacity was estimated to have increased to 23,200 t/yr.

RTI commissioned a second PAM ingot furnace in 2008 and planned to supplement its VAR ingot capacity in 2009. Because of aircraft program delays and adverse market conditions, RTI's plans to construct a 9,070-t/yr sponge plant in Hamilton, MS, were delayed until at least 2011 (RTI International Metals, Inc., 2009, p. 9).

Timet expanded ingot production capacity at its Morgantown, PA, operation with a new EB furnace and several new VAR furnaces. These additions raised Timet's domestic ingot capacity to 46,600 t/yr. An additional EB furnace at Morgantown was scheduled for completion in 2009 (Titanium Metals Corp., 2009, p. 20–21).

In 2008, U.S. production of titanium ingot was 58,600 t, nearly unchanged compared with the record production in 2007. Production of mill products increased by 4% compared with that of 2007 (table 3). U.S. producers of ferrotitanium were RTI Alloys, Canton, OH, and Global Titanium Inc., Detroit, MI. Data on production of ferrotitanium were not available.

TiO_2 Pigment.—TiO_2 pigment is produced from titanium mineral concentrates by either the chloride process or the sulfate process. In the chloride process, rutile is converted to $TiCl_4$ by chlorination in the presence of petroleum coke. $TiCl_4$ is oxidized with air or oxygen at about 1,000° C, and the resulting TiO_2 is calcined to remove residual chlorine and any hydrochloric acid that may have formed in the reaction. Aluminum chloride is added to the $TiCl_4$ to assure that virtually all the titanium is oxidized into the rutile crystal structure. In the sulfate process, ilmenite or titanium slag is reacted with sulfuric acid. Titanium hydroxide is then precipitated by hydrolysis, filtered, and calcined. Although either process may be used to produce pigment, the decision of which process to use is based on numerous factors, including raw material availability, freight, and waste disposal costs. In finishing operations, the crude form of the pigment is milled to produce a controlled distribution of particle size and surface treated or coated to improve its functional behavior in different media. Some typical surface treatments include alumina, organic compounds, and silica.

TiO_2 pigment produced by either process is categorized by crystal form as either anatase or rutile. Rutile pigment is less reactive with the binders in paint when exposed to sunlight than is the anatase pigment and is preferred for use in outdoor paints. Anatase pigment has a bluer tone than rutile, is somewhat softer, and is used mainly in indoor paints and in paper manufacturing. Depending on the manner in which it is produced and subsequently finished, TiO_2 pigment can exhibit a wide range of functional properties, including dispersion, durability, opacity, and tinting.

U.S. production of TiO_2 pigment was 1.35 Mt in 2008, a 6% decrease compared with that in 2007 (table 5). U.S. producers of TiO_2 pigment by the chloride process were DuPont, Louisiana Pigment Co. L.P. (a joint venture of NL Industries, Inc. and Huntsman Corp.), Millennium Inorganic Chemicals Inc., and Tronox Inc. (table 4). TOR Minerals International, Inc. produced a buff TiO_2 pigment from finely ground synthetic rutile.

In 2008, Tronox was facing financial difficulties. In its third quarterly filing with the U.S. Securities and Exchange Commission, Tronox indicated that it may need to seek protection under Chapter 11 of the U.S. Bankruptcy Code (Chang, 2008).

Consumption

Mineral Concentrates.—On a gross weight basis, 95% of the domestic consumption of titanium mineral concentrates was used to produce TiO_2 pigment. The remaining 5% was used to produce miscellaneous other products, including fluxes, metal, and welding rod coatings. Based on TiO_2 content, domestic consumption of titanium mineral concentrates was 1.42 Mt, an 11% decrease compared with that of 2007 (table 6). Consumption data for titanium concentrates were estimated by the USGS owing to insufficient response by industry to the voluntary survey for consumption data.

Metal.—Titanium metal alloys are used for their high strength-to-weight ratio and corrosion resistance. Because of delays in aircraft programs and uncertain market conditions in the fourth quarter, consumption of titanium ingot decreased moderately compared with that of 2007 (table 3).

Domestic shipments of titanium metal mill products increased by 5%. The aerospace industry (79%) was the leading end use for mill products. Other uses included those in the consumer goods, marine, medical, oil and gas, pulp and paper, and specialty chemical industries.

A significant quantity of titanium in the form of ferrotitanium, scrap, and sponge is consumed in the steel and nonferrous alloy industries. In the steel industry, titanium is used for deoxidation, grain-size control, and controlling and stabilizing carbon and nitrogen content. Titanium-intensive steels include interstitial-free, stainless, and high-strength low-alloy steels. Reported domestic consumption of titanium products in steel and other alloys was 11,900 t, a 9% decrease compared with that of 2007 (table 7).

TiO_2 Pigment.—Led by a decrease in the demand for coatings and plastics used in construction and automobiles, domestic consumption of TiO_2 pigment decreased significantly compared with that of 2007 (table 5). The leading uses of TiO_2 pigment, based on TiO_2 pigment shipments in the United States, were paint and coatings (59.2%), plastics and rubber (24.5%), and paper (10.1%). Other uses (6.2%) included catalysts, ceramics, coated fabrics and textiles, floor coverings, printing ink, and roofing granules (table 8).

Stocks

Insufficient data were available to determine yearend consumer inventories of titanium mineral concentrates and TiO_2 pigment producer stocks. Industry reports indicated that in the later half of 2008, the global decrease in the production of mineral concentrates and TiO_2 pigment avoided a buildup in stocks.

Because of high global production of titanium sponge and delays in aircraft production, domestic stocks of sponge increased significantly. Stocks of ingot decreased moderately because of a decrease in production (table 3).

Prices

Titanium mineral concentrate prices are listed in table 9. Prices for bulk ilmenite and rutile concentrates were higher compared with prices in 2007. Published prices for titanium slag were not available. Based on U.S. Customs Service data, the yearend unit value of slag imports ranged from $393 to $407 per metric ton in 2008 compared with $418 to $457 per metric ton in 2007.

The U.S. Department of Labor, Bureau of Labor Statistics (BLS), yearend producer price index (PPI) for TiO_2 pigment increased moderately compared with that of 2007. The monthly PPI started the year at 166, hit a peak of 179 in November, and then fell to 170 by yearend (U.S. Department of Labor, Bureau of Labor Statistics, 2009).

Delays in large aircraft programs, an uncertain global economy, and excess inventory caused prices of titanium metal products to fall significantly. The monthly PPI for titanium mill products reached a high of 260 in April and drifted to a low of 233 by yearend.

Foreign Trade

Mineral Concentrates.—Imports of titanium mineral concentrates include ilmenite, rutile, synthetic rutile, and titaniferous slag. The United States was heavily reliant on imports of titanium mineral concentrates because domestic consumption of titanium minerals greatly exceeded domestic production. In 2008, the TiO_2 content of imports was estimated to be 1.11 Mt, primarily in the form of titaniferous slag (35%) and natural rutile (31%). South Africa, Australia, and Canada, in descending order of quantity, were the leading import sources. The combined value for all forms of titanium concentrate imports in 2008 was $488 million (table 11). After dwindling in 2007, imports of titaniferous iron ore from Canada, classified as ilmenite by the U.S. Census Bureau, increased significantly. Exports of titanium concentrates were minor relative to imports (tables 10 and 11).

Metal.—Imports of titanium metal are primarily in the form of unwrought titanium and scrap. Kazakhstan (50%) and Japan (33%) were the leading sources of imported titanium sponge, while the United Kingdom (25%), Japan (19%), France (15%), and Germany (13%) were the leading sources of imported scrap. The leading import sources of titanium ingot were Germany (57%) and Russia (35%). China (70%) was the major source of titanium powder. Imports of powder and other unwrought forms of titanium decreased by 46% and 42%, respectively, compared with those of 2007.

Imports of titanium wrought products and castings were primarily in the form of plate, sheet, strip, and foil (36%); bar, rod, profiles, and wire (18%); and billets (18%). Russia (67%) and China (13%) were the leading sources of wrought products and castings imports. Reflecting the movement by foreign producers to increase their added-value processing capabilities, imports of wrought products and castings set a record high and increased significantly compared with those of 2007.

Owing to decreased consumption by steel and other alloys, imports of ferrotitanium and ferrosilicon titanium were 2,830 t, a 63% decrease compared with those of 2007. The leading import sources were Canada (54%), the United Kingdom (28%), and Russia (14%). Exports of ferrotitanium and ferrosilicon titanium were 1,620 t, a 24% decrease compared with those of 2007.

TiO_2 Pigment.—The United States continued to be a net exporter of TiO_2 pigment. In 2008, exports exceeded imports by a ratio of 4 to 1. Exports of TiO_2 pigment were 733,000 t, a 7% increase compared with those of 2007. About 91% of TiO_2 pigment exports was in the form of finished pigment with 80% or more TiO_2 content.

During 2008, 183,000 t of TiO_2 pigment was imported, a 17% decrease compared with that in 2007 (table 13). The leading import sources of TiO_2 pigment were Canada (44%), China (9%), and Finland (6%). Pigment imports were primarily in the form of pigment with more than 80% TiO_2.

World Review

Australia.—In Victoria, Iluka was proceeding with the second stage of its Murray Basin project. The project included the construction of a mobile concentrator and the expansion of mineral separation plant capacity. The second stage of development was expected to begin with the Kulwin deposit, but would include the Pirro, Rownack, and Woornack deposits. At the Hamilton mineral separation plant, capacity was being upgraded to accept additional mineral feedstocks from the new mobile concentrator. When the second stage is completed, production capacity from the first and second stages was expected to be about 180,000 t/yr of rutile, and 150,000 t/yr of zircon. In Western Australia, Iluka's synthetic rutile production was hampered by a disruption in the supply of natural gas (Iluka Resources Ltd., 2009b).

In October, Matilda Minerals Ltd. suspended production at its Tiwi mineral sands operation in the Northern Territory. Poor profitability was cited as the cause of the shutdown. Matilda began mining heavy minerals in 2006. By yearend 2008, the company had fallen into voluntary administration to obtain relief from its creditors (Industrial Minerals, 2008c).

Cristal Global's Australian subsidiary, Cristal Australia Pty. Ltd., acquired Australian mineral sands producer Bemax Resources Ltd. Bemax's operations were in the Murray Basin and Western Australia. In 2007, Bemax produced 400,000 t of ilmenite and 57,800 t of rutile. Cristal Global did not plan to idle any of the existing Bemax operations (Millennium Inorganic Chemicals, 2008).

Monto Minerals Ltd. idled its Goondicum mining operation after failing to meet production targets. The company had hoped to produce up to 147,000 t/yr of ilmenite concentrate by 2010. The company cited feed preparation as the cause of the failure. The Goondicum operation produced a suite of minerals including apatite, feldspar, ilmenite, and titanomagnetite. Near yearend, Monto placed itself in voluntary administration (Industrial Minerals, 2008b).

Canada.—In March, the government of Alberta awarded Titanium Corp. Inc. an energy innovation fund grant of $3.5 million. The grant was directed toward achieving environmental and economic benefits from the recovery of hydrocarbons and heavy minerals from oil sands tailings. In 2008, Titanium Corp.'s research and development efforts in Saskatchewan were focused on removing residual bitumen and increasing the recovery of heavy minerals (Titanium Corp. Inc., 2009, p. 10).

Chile.—White Mountain Titanium Corp. (WHT) was proceeding with the exploration and development of its Cerro Blanco rutile deposit. In 2008, WMT completed 12 km of road construction to the deposit. A drilling program, a preliminary design of a processing plant, and an environmental baseline study were also underway. WMT planned to finalize its engineering feasibility study by 2010 (White Mountain Titanium Corp., 2009, p. 14).

China.—Domestic consumption of titanium metal and TiO_2 pigment decreased in China; however, production of both continued to rise. Production of TiO_2 pigment was estimated to be approximately 1 Mt (China Metal Market, 2009).

China's sponge production capacity in 2008 increased to 71,000 t/yr, with the 13 principal operations producing 49,600 t. Titanium ingot capacity was 69,200 t, with 28 operations producing 39,700 t. Titanium metal powder was produced by 5 operations, and production increased to 1,490 t while mill product production from 25 operations increased to 27,700 t (Haflich, 2009).

Aluminum Corp. of China (Chinalco) was moving forward with the construction of a 15,000-t/yr sponge plant in Jiamusi, Heilongjiang Province in northeast China. The plant was expected to begin production in 2010, and plant capacity may eventually increase to 30,000 t/yr based on market conditions. Chinalco's joint-venture partner Aricom Plc planned to supply the plant with titanium concentrates produced in Russia (Steelguru, 2008).

Gambia, The.—Carnegie Minerals Plc withdrew from its mining operations in West Africa and changed its name to Beacon Hill Resources Plc. The move followed a dispute with the Gambian Government in regard to mining rights. The company sold its interest in the West African Projects in Gambia and Senegal to its joint-venture partner Astron Ltd. (Beacon Hill Resources Plc., 2008).

Germany.—ThyssenKrupp Titanium GmbH added an EB furnace to its melting operations in Essen. The new furnace's melt rate was up to 1.2 metric tons per hour and was expected to produce two 15-t slabs per day (RecyclingBizz, 2008).

TiO_2 producers Kemira Oy (Helsinki, Finland) and Rockwood Holdings Inc. (Princeton, NJ) combined their European operations to form a TiO_2 joint-venture company with a yearly production capacity of about 240,000 t of TiO_2 pigment. Rockwood owned 61% and Kemira owned 39% of the new joint venture, Sachtleben Chemie GmbH, which included Kemira's plant in Pori, Finland, and Rockwood Holdings' Sachtleben plant in Duisburg, Germany (Kemira Oyj, 2008).

India.—Government-owned Indian Rare Earth Ltd. (IREL) made plans to significantly expand titanium mineral feedstock production by 2012. IREL planned to double capacity at the Orissa Complex at Chatrapur to 500,000 t/yr of ilmenite. In Tamil Nadu, ilmenite capacity at the Manavalakurichi operation was expected to double to 200,000 t/yr (Industrial Minerals, 2008a).

The Government of India and Titanium Products Private Ltd. (TPPL) formed an understanding to create a titanium project in Orissa that would include facilities for the production of titanium slag, TiO_2 pigment, titanium sponge, and pig iron. TTPL was a joint venture between the Government of Russia and SARAF Group (Ahmedabad, India). The first phase of the project was scheduled to be completed in 2010 and was expected to produce up to 1.1 Mt of titanium slag. A 40,000-t/yr TiO_2 pigment plant was scheduled for completion in 2011 and a 10,000-t/yr titanium sponge plant was expected to begin production in 2012 (Hindu, The, 2008).

Kerala Minerals & Metals Ltd. (KMML) began construction of a 500-t/yr titanium sponge plant. $TiCl_4$ was to be supplied to the plant from KMML's Chavara TiO_2 pigment plant. The plant was scheduled to be in production by June 2010 (Kerala Minerals & Metals Ltd., undated).

Japan.—Shipments of titanium sponge increased to a record 38,900 t, a slight increase from those in 2007. Increased sponge production resulted in increased exports and higher inventory levels (Roskill's Letters from Japan, 2009b). Japan's TiO_2 pigment production in 2008 was 225,000 t, a 9% decrease compared with that in 2007. Domestic TiO_2 pigment shipments decreased by 7% owing primarily to decreased consumption in paints and coatings (Roskill's Letters from Japan, 2009a).

Toho Titanium Co. Ltd. completed construction of a new EM furnace at its Yahata operations, increasing titanium ingot capacity to 19,000 t/yr from 9,000 t/yr (Platts Metals Week, 2008). Toho expected to increase its titanium sponge capacity to 28,000 t/yr from 16,000 t/yr when the Wakamatsu plant in Fukuoka Prefecture is completed in 2010 (Nippon Mining Holdings, Inc., 2008, p. 25–26).

Osaka Titanium Technologies Co. increased its sponge capacity to 32,000 t/yr from 24,000 t/yr; however, based on market conditions, production levels were reduced, and plans to expand sponge capacity to 41,000 t/yr were delayed. Osaka commissioned its Kishiwada Works adding 3,000 t/yr of ingot production capacity. Together, Osaka's Amagasaki and Kishiwada plants had 10,000 t/yr of titanium ingot production capacity (Osaka Titanium Technologies Co., 2008, p. 12–13).

Kobe Steel Ltd. completed construction of a melt shop at the Takasago Works that increased ingot production capacity by 30% to an estimated 11,000 t/yr (Kobe Steel Ltd., 2008, p. 19).

Kazakhstan.—Ust-Kamenogorsk Titanium-Magnesium Complex (UKTMP), a leading source of titanium sponge, was expanding its capabilities beyond sponge production to produce ingot. A 7,000-t/yr ingot plant was expected to be commissioned in 2010 (Metal-Pages Ltd., 2008).

Kenya.—Tiomin Resources Inc. and Jinchuan Group Ltd. (China) entered into an understanding wherein Jinchuan would acquire 70% of Tiomin Kenya Ltd. (TKL) (a subsidiary of Tiomin) that owned the Kwale Mineral Sands Project. Jinchuan Group would provide financing to develop Kwale. At yearend, TKL's Kwale mining lease remained subject to a force majeure in effect since 2006 (Tiomin Resources Inc., 2008).

Mozambique.—Production at Kenmare Resources plc's newly commissioned Moma heavy-minerals operation was well below its 800,000-t/yr design capacity. Processing difficulties delayed a ramp up in production, and shipments of ilmenite concentrate were limited to 268,000 t in 2008 (Kenmare Resources plc, 2009, p. 6–9).

Norway.—The French mining and metallurgical company Eramet Group acquired 56% interest in Oslo-based Tinfos AS. Tinfos operations in Norway produced hydroelectric power, pig iron, silicomanganese, and TiO_2 slag. Following the acquisition, Tinfos was split into two subsidiaries to separate its assets. The Tinfos TiO_2 slag operation in Tyssedal was included under the Eralloys subsidiary. Plans to increase Eramet interest in Eralloys to 100% were canceled (Vidalon, 2008).

Russia.—A new titanium sponge plant was commissioned at the Solikamsk Magnesium Works (SMW). Although production in 2008 was less than 100 t, the plant was expected to achieve a capacity of 2,500 t/yr, with future plans to increase capacity to 5,000 t/yr. SMW shipments of $TiCl_4$ were reported as 2,980 TiO_2 equivalent in 2008, a 20% decrease compared with those in 2007 (Metal-Pages Ltd., 2009a, b).

Sierra Leone.—In July, the newly commission second dredge at Titanium Resources Group Ltd.'s Sierra Rutile operation capsized. The second dredge had been expected to double production capacity. Instead, rutile production decreased by 5% to 18,000 t. Once begun, repairs to the second dredge were expected to take 14 months. At yearend, the repairs on the second dredge had not begun because of insufficient funding (Titanium Resources Group Ltd., 2009, p. 7).

South Africa.—Exxaro Resources completed the acquisition of West African mineral sands producer Namakwa Sands Pty. Ltd. from Anglo American Corp. The acquisition included a heavy-mineral sands mine at Brand-se Baai, a mineral separation plant at Koekenaap, and a TiO_2 slag operation at Saldanha Bay. Production of titanium mineral concentrates at Namakwa Sands increased moderately despite electrical power cutbacks during the first quarter which had affected most industries in the country. In 2008, Namakwa Sands produced 27,000 t of rutile, 135,000 t of chloride-grade TiO_2 slag, and 24,000 t of sulfate-grade TiO_2 slag. In February, a water ingress idled one of two TiO_2 slag furnaces at Exxaro's KZN Sands operations in KwaZulu-Natal. Subsequently, production of titanium mineral concentrates decreased significantly to 19,000 t of rutile, 95,000 t of chloride-grade slag, and 18,000 t of sulfate-grade slag (Exxaro Resources Ltd., 2009, p. 13, 37).

Richards Bay Minerals was proceeding with the construction of a tailings treatment plant to recover valuable minerals contained in tailings from past and ongoing mineral separation plant operations. Construction was expected to be completed in 2010 and was expected to extend the mine life by 5 years (Prinsloo, 2008).

Ukraine.—The nation's sole titanium sponge producer, Zaporozhye Titanium and Magnesium Combine (ZTMK), increased production to 9,930 t, a record since the plant was restarted in 1998. After the dissolution of the Soviet Union, the plant had been idle from 1993 to 1997. At yearend, ZTMK commissioned a 1,000-t/yr EB ingot furnace and made plans to increase sponge capacity by 4,300 t/yr (Metal-Pages Ltd., 2009c).

United Kingdom.—Timet increased titanium ingot capacity at its Witton operation to 10,700 t/yr with the addition of a 2,000-t/yr VAR furnace. Ingot produced at Witton was primarily used for Timet's own forging operation at Witton (Titanium Metals Corp., 2009, p. 22).

Vietnam.—At yearend, the Government of Vietnam implemented a ban on all heavy-mineral concentrate exports. If the ban were lifted to help domestic producers, the export tariff for titanium mineral concentrates would be 20% (Mineral Sands Report, 2008).

Outlook

For the foreseeable future, the market for titanium minerals will be determined by the production of TiO_2 pigment. Unless new mines are developed, the United States heavy reliance on imports of titanium mineral concentrates is likely to increase as existing mines are depleted within the next 10 years.

During the next decade, global demand growth for TiO_2 was expected to track with the total global gross domestic product and the production of paint, paper, and plastics. Higher-than-average growth was expected in Asia. China in particular was expected to lead world growth in production and consumption. TiO_2 production capacity in China was scheduled to double by the end of the decade. During the next several years, prices for TiO_2 pigment were expected to rise because of increasing costs for caustic soda, chlorine, coke, and energy.

Aerospace, defense, and industrial uses were expected to strongly influence consumption of titanium metal for the foreseeable future. Commercial aircraft will remain a major consumer of titanium metal. The growth of the global airplane fleet was projected to average 3.2% per year from 2008 to 2028 (Boeing Co., The, 2009, p. 3). In the near term (1 to 2 years), however, global titanium sponge consumption was expected to decrease because of delayed aircraft construction and reduced industrial output. Government and private industry programs were working to commercialize lower cost methods of producing titanium metal. At least one of these methods was expected to reach commercialization during the next few years.

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TABLE 1

SALIENT TITANIUM STATISTICS[1]

		2004	2005	2006	2007	2008
United States:						
Mineral concentrate:						
Imports for consumption	metric tons	1,060,000	1,190,000	1,230,000	1,460,000	1,360,000
Consumption[2]	do.	1,920,000	1,720,000 e	1,870,000 e	1,950,000 e	1,760,000 e
Sponge metal:						
Imports for consumption	do.	11,900	15,800	24,400	25,900	23,900
Consumption	do.	21,200	26,100	28,400	33,700	W
Price, yearend[3]	dollars per pound	3.55–6.44	3.46–12.22	5.87–12.84	6.33–7.06	6.16–8.02
Titanium dioxide pigment:						
Production	metric tons	1,540,000	1,310,000	1,370,000	1,440,000	1,350,000
Imports for consumption	do.	264,000	341,000	288,000	221,000	183,000
Consumption, apparent	do.	1,170,000 4	1,130,000 4	1,080,000 5	979,000 5	800,000 5
Producer price index, yearend:[6]	(1982=100)	158	172	165	162	170
World, production:						
Ilmenite concentrate[7]	metric tons	5,850,000 r	6,050,000 r	6,790,000 r	6,940,000 r	6,790,000
Rutile concentrate, natural[8]	do.	354,000	375,000 r	512,000	601,000 r	621,000
Titaniferous slag[e]	do.	1,880,000	1,880,000	2,160,000	2,260,000	2,230,000

[e]Estimated. [r]Revised. do. Ditto. W Withheld to avoid disclosing company proprietary data.

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

[2]Excludes consumption used to produce synthetic rutile.

[3]Landed duty-paid unit based on U.S. imports for consumption.

[4]Production plus imports minus exports plus stock decrease or minus stock increase.

[5]Production plus imports minus exports. Excludes stock changes.

[6]Source: U.S. Department of Labor, Bureau of Labor Statistics.

[7]Includes U.S. production of ilmenite, leucoxene, and rutile rounded to one significant digit to avoid disclosing company proprietary data.

[8]U.S. production of rutile included with ilmenite to avoid disclosing company proprietary data.

TABLE 2

U.S. TITANIUM METAL PRODUCTION CAPACITY IN 2008[1, 2]

(Metric tons per year)

Company	Plant location	Yearend capacity[e]	
		Sponge	Ingot[3]
Alcoa Howmet	Whitehall, MI	--	3,200
Allegheny Technologies Inc.	Albany, OR	9,980	10,900
Do.	Monroe, NC	--	23,200
Do.	Richland, WA	--	10,000
Alloy Works LLC	Greensboro, NC	--	1,800
Honeywell Electronic Materials Inc.	Salt Lake City, UT	500	--
Perryman Co.	Houston, PA	--	1,800
RTI International Metals, Inc.	Niles, OH	--	13,600
Titanium Metals Corp.	Henderson, NV	12,600	12,300
Do.	Morgantown, PA	--	33,500
Do.	Vallejo, CA	--	800
Total		23,100	111,000

[e]Estimated. Do. Ditto. -- Zero.

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

[2]Estimated operating capacity based on 7-day-per-week full production.

[3]Includes electron-beam, plasma, and vacuum-arc-remelting capacity.

TABLE 3

COMPONENTS OF U.S. TITANIUM METAL SUPPLY AND DEMAND[1]

(Metric tons)

Component	2007	2008
Production:		
Ingot	59,200	58,600
Mill products	38,200	39,700
Exports:		
Waste and scrap	9,510	8,180
Sponge	2,000	2,370
Other unwrought	3,270	3,440
Wrought products and castings	15,500	19,000
Total	30,300	33,000
Imports:		
Waste and scrap	12,200	10,400
Sponge	25,900	23,900
Other unwrought	2,610	1,540
Wrought products and castings	5,350	8,350
Total	46,100	44,200
Stocks, industry, yearend:		
Sponge	7,820	14,200
Scrap	12,600	W
Ingot	5,150	3,590
Consumption, reported:		
Sponge	33,700	W
Scrap	23,800	23,200
Ingot	50,300	47,700
Shipments:		
Ingot	16,000	17,200
Mill products (net shipments):		
Forging and extrusion billet	12,400	12,300
Plate, sheet, strip	14,700	15,600
Rod, bar, fastener stock, wire	5,350	(3)
Other[2]	696	6,940
Total	33,200	34,800
Castings (shipments)	1,760	W
Receipts, scrap:		
Home	12,300	(4)
Purchased	18,800	(4)
Total	31,100	31,900

W Withheld to avoid disclosing company proprietary data.

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

[2]Data for pipe, tube, and other have been combined to avoid disclosing company proprietary data.

[3]Included with "Other."

[4]Withheld to avoid disclosing company proprietary data; included in "Total."

TABLE 4

U.S. PRODUCERS OF TITANIUM DIOXIDE PIGMENT IN 2008[1, 2, 3]

(Metric tons per year)

Company	Plant location	Yearend capacity[4]
Du Pont Titanium Technologies	De Lisle, MS	340,000
Do.	Edgemoor, DE	154,000
Do.	New Johnsonville, TN	380,000
Louisiana Pigment Co. L.P.	Lake Charles, LA	146,000
Millennium Inorganic Chemicals Inc.	Ashtabula, OH	220,000
Do.	Baltimore, MD	50,000
Tronox Inc.	Hamilton, MS	225,000
Do.	Savannah, GA	110,000
Total		1,630,000

Do. Ditto.

[1]Estimated operating capacity based on 7-day-per-week full production.

[2]Table does not include TOR Minerals International, Inc.'s Corpus Christi, TX, production capacity of about 26,400 metric tons per year of buff TiO_2 pigment that is produced by refining and fine grinding of synthetic rutile.

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

[4]All plants use the chloride process to manufacture TiO_2 pigment.

TABLE 5

COMPONENTS OF U.S. TITANIUM DIOXIDE PIGMENT SUPPLY AND DEMAND[1]

		2007		2008	
		Gross weight	TiO_2 content	Gross weight	TiO_2 content
Production[2]	metric tons	1,440,000	1,360,000 e	1,350,000	1,360,000 e
Shipments:[3]					
Quantity	do.	1,480,000	1,320,000 e	1,390,000	1,300,000 e
Value	thousands	$2,760,000	XX	$3,070,000	XX
Exports	metric tons	682,000	641,000 e	733,000	688,000 e
Imports for consumption	do.	221,000	208,000 e	183,000	172,000 e
Consumption, apparent[e, 4]	do.	979,000	925,000	800,000	751,000

[e]Estimated. do. Ditto. XX Not applicable.

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

[2]Excludes production of buff pigment.

[3]Includes interplant transfers.

[4]Production plus imports minus exports. Excludes stock changes.

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

TABLE 6

ESTIMATED U.S. CONSUMPTION OF TITANIUM CONCENTRATE[1, 2]

(Metric tons)

	2007		2008	
	Gross weight	TiO_2 content	Gross weight	TiO_2 content
Pigment	1,860,000	NA	1,670,000	NA
Miscellaneous[3]	85,000	NA	95,000	NA
Total	1,950,000	1,600,000	1,760,000	1,420,000

NA Not available.

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

[2]Includes a mixed product containing altered ilmenite, leucoxene, and rutile.

[3]Includes alloys, carbide, ceramics, chemicals, glass fibers, titanium metal, and welding-rod coatings and fluxes.

TABLE 7

U.S. CONSUMPTION OF TITANIUM IN STEEL AND OTHER ALLOYS[1, 2]

(Metric tons)

	2007	2008
Steel:		
Carbon steel	6,460	5,930
Stainless and heat-resisting steel	3,340	3,270
Other alloy steel[3]	741	636
Total steel	10,500	9,840
Cast irons	14	16
Superalloys	1,200	1,060
Alloys, other than above	1,360	1,030
Miscellaneous and unspecified	41	40
Grand total	13,200	12,000

[1]Includes ferrotitanium, scrap, sponge, and other titanium additives.

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

[3]Includes high-strength low-alloy and tool steel.

TABLE 8

U.S. DISTRIBUTION OF TITANIUM PIGMENT SHIPMENTS, TITANIUM DIOXIDE CONTENT, BY INDUSTRY[1]

(Percent)

Industry	2007	2008
Paint, varnish, lacquer	59.1	59.2
Paper	11.6	10.1
Plastics and rubber	23.8	24.5
Other[2]	5.5	6.2
Total	100.0	100.0

[1]Excludes exports.

[2]Includes agricultural, building materials, ceramics, coated fabrics and textiles, cosmetics, food, paper, and printing ink. Also includes shipments to distributors.

TABLE 9

YEAREND PRICES OF TITANIUM PRODUCTS

		2007	2008
Concentrate:			
Ilmenite, free on board (f.o.b.) Australian ports[1]	dollars per metric ton	75–85	84–137
Rutile, bagged, f.o.b. Australian ports[1]	do.	650–700	675–725
Rutile, bulk, f.o.b. Australian ports[1]	do.	475–500	500–550
Titaniferous slag, import, 80% to 95% TiO_2[2]	do.	418–457	393–407
Metal:			
Sponge import[2]	dollars per pound	6.33–7.06	6.16–8.02
Scrap, turnings, unproccessed[3]	do.	2.00–2.05	0.45–0.55
Ferrotitanium, 70% Ti[3]	do.	3.80–3.85	2.95–3.05
Mill products[4]	producer price index	277	233
Titanium dioxide pigment[4]	do.	162	170

do. Ditto.

[1]Source: Industrial Minerals.

[2]Landed duty-paid unit value based on U.S. imports for consumption.

[3]Source: Platts Metals Week.

[4]1982=100. Source: U.S. Department of Labor, Bureau of Labor Statistics.

TABLE 10

U.S. EXPORTS OF TITANIUM BY CLASS[1]

Class	HTS[2]	2007 Quantity (metric tons)	2007 Value (thousands)	2008 Quantity (metric tons)	2008 Value (thousands)
Metal:					
Scrap	8108.30.0000	9,510	$67,300	8,180	$52,000
Unwrought:					
Sponge	8108.20.0010	2,000	20,300	2,370	41,100
Ingot	8108.20.0030	2,270	44,200	725	19,500
Other	8108.20.0090	1,000	31,800	2,710	51,300
Wrought:					
Billet	8108.90.6010	2,730	149,000	3,200	135,000
Bloom, sheet bar, slab	8108.90.6020	1,280	38,600	1,980	60,900
Bar, rod, profile, wire	8108.90.6031	2,840	202,000	3,300	210,000
Other	8108.90.8000	8,670	638,000	10,500	714,000
Total		30,300	1,190,000	33,000	1,280,000
Ferrotitanium and ferrosilicon titanium	7202.91.0000	2,120	11,500	1,620	9,090
Ores and concentrates	2614.00.0000	9,730	5,140	14,900	8,590
Pigment:					
80% or more titanium dioxide pigment	3206.11.0000	564,000	1,020,000	668,000	1,310,000
Other titanium dioxide pigment	3206.19.0000	111,000	241,000	60,200	152,000
Unfinished titanium dioxide[3]	2823.00.0000	7,200	15,900	5,040	10,400
Total		682,000	1,280,000	733,000	1,470,000

[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]Unmixed and not surface treated.

Source: U.S. Census Bureau.

TABLE 11

U.S. IMPORTS FOR CONSUMPTION OF TITANIUM CONCENTRATE, BY COUNTRY[1]

Concentrate and country	HTS[2]	2007 Quantity (metric tons)	2007 Value (thousands)	2008 Quantity (metric tons)	2008 Value (thousands)
Ilmenite:	2614.00.6020				
Australia		228,000	$22,900	218,000	$23,200
Mozambique		--	--	98,600	8,050
South Africa		5,990	2,740	87,500	33,700
Other		12,000 r	1,200 r	29,000	3,690
Total		246,000	26,900	433,000	68,600
Titaniferous slag:	2620.99.5000				
Canada		193,000	84,100	106,000	45,700
South Africa		475,000	188,000	355,000	141,000
Other[3]		80,700	29,900	--	--
Total		749,000	302,000	461,000	187,000
Rutile, natural:	2614.00.6040				
Australia		145,000	67,600	136,000	77,200
Canada		34,300	17,000	39,700	17,300
South Africa		170,000	77,100	176,000	84,800
Other[3]		29,200 r	17,700 r	12,900	7,840
Total		379,000	177,000	365,000	187,000
Rutile, synthetic:	2614.00.3000				
Australia		64,700	15,400	111,000	40,300
South Africa		15,000	5,960	5,340	2,260
Other[3]		5,130 r	2,510 r	5,400	2,810
Total		84,800	23,900	122,000	45,400
Titaniferous iron ore, Canada[4]	2614.00.6020	72	8	140,000	44,600

rRevised. -- 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]All or part of these data have been referred to the U.S. Census Bureau for verification.

[4]Includes materials consumed for purposes other than production of titanium commodities, principally heavy aggregate and steel-furnace flux. Titaniferous iron ore from Canada is classified as ilmenite under the HTS.

Source: U.S. Census Bureau; data adjusted by the U.S. Geological Survey.

TABLE 12

U.S. IMPORTS FOR CONSUMPTION OF TITANIUM METAL, BY CLASS AND COUNTRY[1]

Class and country	HTS[2]	2007 Quantity (metric tons)	2007 Value (thousands)	2008 Quantity (metric tons)	2008 Value (thousands)
Waste and scrap:	8108.30.0000				
Canada		908	$5,330	728	$2,950
China		275	3,510	199	1,550
France		1,670	17,900	1,560	14,000
Germany		1,430	25,800	1,310	10,500
Israel		231	2,480	363	2,020
Japan		2,210	18,800	1,960	12,600
Mexico		245	1,160	233	711
Russia		472	9,950	158	2,030
Taiwan		953	13,100	441	2,450
United Kingdom		2,700	22,500	2,660	14,200
Other		1,140 r	12,700 r	832	5,870
Total		12,200	133,000	10,400	68,900
Unwrought:					
Sponge:	8108.20.0010				
China		2,220	36,000	1,510	18,500
Japan		8,250	118,000	7,860	121,000
Kazakhstan[e]		13,800	142,000	12,000	110,000
Ukraine		703	11,100	1,540	18,300
Other		973 r	13,800 r	966	10,000
Total		25,900	321,000	23,900	278,000
Ingot:	8108.20.0030				
Germany		884	30,000	771	25,200
Russia		1,300	21,800	466	9,370
Other		78	1,720	107	2,220
Total		2,270	53,500	1,340	36,800
Powder:	8108.20.0015				
China		218	6,310	94	2,420
Japan		24	2,200	17	3,520
Other		4	1,280	23	1,780
Total		246	9,790	134	7,710
Other:	8108.20.0091				
Canada		1	59	9	969
China		17	228	17	187
France		19	587	(4)	35
Germany		34	176	7	61
Netherlands		2	62	19	156
Taiwan		17	214	--	--
United Kingdom		5	146	6	55
Other		4 r	155 r	1	138
Total		101	1,630	59	1,570
Wrought products and castings:[3]	8108.90.3030, 8108.90.3060, 8108.90.6010, 8108.90.6020, 8108.90.6031, 8108.90.6045, 8108.90.6060, 8108.90.6075				
China		920	38,400	1,070	45,700
Germany		90	7,100	356	21,900
Japan		372	22,600	325	19,300
Russia		3,290	105,000	5,590	178,000
United Kingdom		176	14,300	377	32,200
Other		497 r	41,100 r	625	51,000
Total		5,350	229,000	8,350	349,000
Ferrotitanium and ferrosilicon titanium	7202.91.0000	7,620	35,300	2,830	14,900

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

TABLE 12—Continued

U.S. IMPORTS FOR CONSUMPTION OF TITANIUM METAL, BY CLASS AND COUNTRY[1]

[3]Includes bar, billet, bloom, castings, foil, pipe, plate, profile, rod, sheet, sheet bar, slab, strip, tube, wire, and other.
[4]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 13

U.S. IMPORTS FOR CONSUMPTION OF TITANIUM PIGMENT, BY COUNTRY[1]

		2007		2008	
Country	HTS[2]	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
80% or more titanium dioxide pigment:	3206.11.0000				
Belgium		4,920	$8,950	2,820	$5,120
Canada		81,100	161,000	74,300	150,000
China		12,900	19,100	6,590	12,800
Finland		12,000	24,200	9,260	20,000
Germany		5,960	13,400	4,730	11,100
Italy		6,080	10,200	6,210	10,800
Japan		3,440	10,200	2,940	11,500
Mexico		3,320	6,070	3,290	5,730
Netherlands		3,790	7,520	3,200	5,950
Spain		10,500	17,200	5,070	8,840
Ukraine		4,060	6,150	4,450	7,620
United Kingdom		3,970	6,820	1,110	2,110
Other		15,000 r	26,200 r	11,200	19,200
Total		167,000	317,000	135,000	271,000
Other titanium dioxide:	3206.19.0000				
Canada		2,340	12,400	5,930	20,300
China		825	2,440	1,070	4,510
Finland		184	2,240	231	3,040
France		275	634	515	933
Germany		688	2,410	615	2,430
Japan		698	5,780	719	6,460
Korea, Republic of		920	1,690	630	1,000
Other		631 r	4,840 r	841	4,430
Total		6,570	32,400	10,500	43,100
Unfinished titanium dioxide:[3]	2823.00.0000				
China		14,600	21,300	9,620	17,800
Czech Republic		2,730	4,990	2,290	4,240
France		4,110	9,390	2,800	10,500
Germany		6,250	13,700	4,510	10,400
India		1,500	2,060	742	1,050
Japan		4,820	13,100	5,710	15,600
Korea, Republic of		4,940	6,270	2,880	4,770
United Kingdom		7,080	9,580	5,290	6,680
Other		1,310 r	2,820 r	3,250	8,100
Total		47,300	83,200	37,100	79,300
Grand total		221,000	432,000	183,000	393,000

[r]Revised.
[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]Unmixed and not surface treated.

Source: U.S. Census Bureau.

TABLE 14

TITANIUM: WORLD PRODUCTION OF MINERAL CONCENTRATES, BY COUNTRY[1, 2]

(Metric tons)

Concentrate type and country	2004	2005	2006	2007	2008
Ilmenite and leucoxene:[3, 4]					
Australia	1,965,000	2,080,000	2,508,000 r	2,503,000 r	2,199,000
Brazil[5]	75,000 r	75,000 r	87,000 r	92,000 r	90,000
China[e]	840,000	900,000	1,000,000	1,100,000	1,100,000
Egypt	-- r	-- r	-- r	-- r	--
India[e]	621,000	686,000	690,000	700,000	720,000
Kazakhstan[e]	11,670 [6]	10,000	25,000	25,000	25,000
Malaysia	61,471	38,196	45,649	59,310 r	50,000 e
Mozambique	--	--	--	140,515 r	328,875
Norway[e]	860,000	860,000	850,000	850,000	910,000
Sierra Leone	--	--	13,819	15,750	17,528
Ukraine	370,000 e	375,000 e	470,000	500,000	500,000 e
United States[e, 7]	500,000	500,000	500,000	400,000	300,000
Vietnam[e, 8]	550,000	523,000	605,000	550,000 r	550,000
Total[9]	5,850,000 r	6,050,000 r	6,790,000 r	6,940,000 r	6,790,000
Rutile:[4]					
Australia	162,000	177,000	232,000	312,000 r	325,000
Brazil[5]	2,500 r	2,500 r	2,500 r	2,500 r	2,500 e
India[e]	19,600 r	20,100 r	21,000	21,000	21,000
Mozambique	--	--	--	8,782 r	6,552
Sierra Leone	--	--	73,802	82,527 r	78,908
South Africa[e]	110,000	115,000	123,000	114,000	127,000
Ukraine[e]	60,000	60,000	60,000	60,000	60,000
United States	(10)	(10)	(10)	(10)	(10)
Total	354,000	375,000 r	512,000	601,000 r	621,000
Titaniferous slag:[e, 11]					
Canada[e]	863,000	860,000	930,000	960,000	1,000,000
South Africa[e]	1,020,000	1,020,000	1,230,000	1,295,000	1,230,000
Total	1,880,000	1,880,000	2,160,000	2,260,000	2,230,000

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

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

[2]Table includes data available through July 7, 2009.

[3]Ilmenite is also produced in Canada and South Africa, but this output is not included here because most of it is duplicative of output reported under "Titaniferous slag," and the rest is used for purposes other than production of titanium commodities, principally steel furnace flux and heavy aggregate.

[4]Small amounts of titanium minerals were reportedly produced in various countries; information, however, is inadequate to make reliable estimates of output levels.

[5]Excludes production of unbeneficiated anatase ore.

[6]Reported figure.

[7]Includes rutile to avoid disclosing company proprietary data. Rounded to one significant digit.

[8]Estimate based on import statistics from trading partners (primarily China and Japan).

[9]Includes U.S. production, rounded to one significant digit, of ilmenite, leucoxene, and rutile to avoid disclosing company proprietary data.

[10]Included with ilmenite to avoid disclosing company proprietary data.

[11]Slag is also produced in Norway, Kazakhstan, and Russia, but this output is not included under "Titaniferous slag" to avoid duplicative reporting.