



# 2017 Minerals Yearbook

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## ZIRCONIUM AND HAFNIUM [ADVANCE RELEASE]

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# ZIRCONIUM AND HAFNIUM

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In 2017, production of zirconium mineral concentrates in the United States increased, and estimated production of milled zircon increased slightly from that of 2016. U.S. imports of zirconium ore and mineral concentrates decreased by 3%, but exports increased by almost tenfold owing to the operations of a new producer of zirconium mineral concentrates in Florida (table 1). World production of zirconium mineral concentrates in 2017 was about 1.47 million metric tons (Mt), a 2% increase from the revised 2016 production total (table 5).

The primary source of zirconium was the mineral zircon ( $ZrSiO_4$ ), principally found in heavy-mineral sands. A relatively small quantity of zirconium was derived from the mineral baddeleyite, a natural form of zirconia [zirconium oxide ( $ZrO_2$ )] recovered from a single source in Kovdor, Russia. In 2017, the leading producers of zircon were Australia and South Africa. Zircon was also the primary source of hafnium; zirconium and hafnium are contained in zircon at a ratio of about 34:1 (Jones and others, 2017, p. V5). Zirconium and hafnium metals were produced in China, France, India, Russia, and the United States.

## Production

Zircon is a coproduct of the mining and processing of heavy-mineral sands for the titanium minerals ilmenite and rutile. In 2017, the U.S. producers of zircon were The Chemours Co. (Wilmington, DE), Southern Ionics Inc. (West Point, MS), and Twin Pines Minerals, LLC (Starke, FL). Chemours produced zirconium mineral concentrates from its operation near Starke, FL, and Southern Ionics produced zirconium mineral concentrates from its operation in Nahunta, GA. In February, Twin Pines Minerals began processing existing Chemours mine tailings for zircon in Starke, FL. Data on domestic production and consumption of zirconium mineral concentrates were rounded to one significant digit to avoid disclosing company proprietary data.

U.S. producers of zirconium and hafnium metal were ATI Wah Chang (an Allegheny Technologies, Inc. business unit) in Albany, OR, and Western Zirconium (a subsidiary of Westinghouse Electric Co.) in Ogden, UT.

Data for zirconium and hafnium manufactured materials were collected from a voluntary survey of domestic operations. Of the 38 operations surveyed, 10 responded, and data for nonrespondents were estimated on the basis of prior-year levels. Domestic production of milled zircon was 49,900 metric tons (t) in 2017. Insufficient data were available to determine stocks of zirconium mineral concentrates as well as production of zirconium chemicals and zirconium metal (table 1).

## Consumption

Globally, the leading end uses for zircon were, in descending order, ceramics, zirconium-based chemicals, refractories,

and foundry and casting applications (Blackwell, 2018, p. 21). Zircon sand is preferred in casting applications where high-quality finishes and tight tolerances are required owing to its lower expansion coefficient and greater stability at high temperatures compared with other materials. Zircon recovered from hard-rock mining was valued as a natural gemstone, and zirconia powder in minor quantities was processed to produce cubic zirconia, a synthetic gemstone and diamond simulant.

Zirconium metal was used in corrosive environments, nuclear fuel cladding, and various specialty alloys. The principal uses of hafnium were in high-temperature ceramics, nickel-base superalloys, nozzles for plasma arc metal cutting, and nuclear control rods.

Zirconia exhibits high light reflectivity and good thermal stability and was primarily used as an opacifier and pigment in glazes and colors used for pottery and other ceramic products. Yttria-stabilized zirconia (YSZ) was used in the manufacture of oxygen sensors that control combustion in automobile engines and furnaces. YSZ was also used in the manufacture of a diverse array of products, including cubic zirconia, fiber optic connector components, refractory coatings, and engineering and structural ceramics. YSZ was used in biomedical applications, such as dental bridges, crowns, and inlays, because it has two to three times the fracture resistance and 1.4 times the strength of alternative alumina products.

Zircon, used for facings on foundry molds, increases resistance to metal penetration and gives a uniform finish to castings. Milled or ground zircon was used in refractory paints for coating the surfaces of molds. Refractory bricks and blocks containing zircon were used in furnaces and hearths for containing molten metals. Fused-cast and bonded alumina-zirconia-silica-base refractories were used in glass-tank furnaces.

Baddeleyite was used principally in the manufacture of alumina-zirconia abrasives and in ceramic colors and refractories. Ammonium- and potassium-zirconium carbonates were used as antiperspirants, paper and board coatings, and in printing and paper manufacturing. Zirconium chemicals were also used in inks to promote adhesion to metals and plastics.

Because of its low thermal neutron absorption cross section, hafnium-free zirconium metal was used as cladding for nuclear fuel rod tubes. Hafnium was used in nuclear control rods because of its high thermal neutron absorption cross section. Commercial-grade zirconium, unlike nuclear grade, contains hafnium and was used in chemical process industries because of its excellent corrosion resistance. Hafnium metal also was used as an additive in superalloys.

## Prices

The 2017 yearend published price range of standard-grade bulk domestic zircon concentrate was

\$950 to \$1,100 per metric ton, unchanged from yearend prices of 2016 (table 2). The average unit value of imported zirconium ore and concentrates in 2017 was \$1,012 per metric ton, a slight increase from that of 2016 (table 4). The published yearend price range of abrasive and refractory zirconia was \$6,150 to \$7,150 per metric ton, slightly higher than that of the previous year (table 2). Weighted average prices of zircon products from the largest global producer of zircon products, Iluka Resources Ltd., (Australia) was \$958 per metric ton for 2017, an increase of 18% from that of 2016 (Iluka Resources Ltd., 2018, p. 40).

In 2017, the average duty-paid unit value of imported unwrought zirconium (including sponge and powder) from China, the leading source of United States zirconium imports, decreased by almost two-thirds from that of 2016, to \$12 per kilogram. The average duty-paid unit value of zirconium from France, a major producer of nuclear-grade zirconium, was \$44 per kilogram, a decrease of 6% from that of 2016 (table 4). The average value of unwrought hafnium was \$912 per kilogram in 2017, a decrease of 16% from that of the previous year (Argus Media group—Argus Metals International, 2018).

### Foreign Trade

In 2017, exports of zirconium ore and concentrates were 48,400 t, an almost tenfold increase from 5,050 t in 2016 (table 3). Imports of zirconium ore and concentrates totaled 37,300 t, a decrease of 3% from those of 2016. South Africa, Senegal, and Australia supplied most of the zirconium ore and concentrates (53%, 24%, and 20%, respectively) into the United States (table 4).

Most zirconium metal, excluding ferrozirconium, was exported in wrought products classified as “Other zirconium and articles thereof” under the harmonized-system-based Schedule B code 8109.90.0000 (table 3). Exports of zirconium metal totaled 972 t in 2017, a 23% increase from those of 2016 (table 3). Most zirconium metal was imported as unwrought zirconium or zirconium metal powder under Harmonized Tariff Schedule of the United States (HTS) code 8109.20.0000. The United States imported 656 t of zirconium metal in 2017, a decrease of 22% from that of 2016 (table 4). Imports of hafnium metal, HTS code 8112.92.2000, totaled 113 t, a decrease of 37% from imports in 2016 (table 4). Imports of ferrozirconium alloys were 161 t in 2017, an increase of 175% from those in 2016.

### World Review

Although zircon inventories and production were sufficient for global demand at the beginning of 2017, Iluka’s suspension of operations at the Jacinth-Ambrosia Mine, which began in April 2016 and continued until December 2017, contributed to a tightening of zircon supply, which was evident at yearend. Owing to depleted supplies, shortages of zircon resulted in the increased prices of downstream products (Iluka Resources Ltd., 2018, p. 5; Perks, 2018).

**Australia.**—Iluka produced 312,000 t of zircon from its operations in Australia, a decrease of 10% from that of 2016. In December, Iluka announced the resumption of mining activity at the Jacinth-Ambrosia Mine in the Eucla basin of South Australia. Iluka had suspended mining activities at the mine

in April 2016 to draw down the heavy-mineral-concentrate inventory held there. Jacinth-Ambrosia was the primary source of zircon for Iluka. Also in December, the Cataby project in Western Australia was approved. With a projected mine life of 8.5 years, zircon production was anticipated to average about 50,000 metric tons per year and was expected to begin in the second quarter of 2019 (Iluka Resources Ltd., 2017, p. 16–17; 2018, p. 23–25).

MZI Resources Ltd. produced 18,341 t of zircon concentrate at its Keysbrook project in Western Australia, an increase of 15% from that of 2016 (MZI Resources Ltd., 2018).

Tronox Ltd. produced 34,000 t of zircon from its Cooljarloo Mine in Western Australia, an increase of 6% from production in 2016. Total heavy-mineral reserves at yearend 2017 for Tronox’s operations in Western Australia were 481 Mt of ore containing 11.1 Mt of heavy minerals and 1.2 Mt of zircon, a 4% decrease from reported reserves at yearend 2016 (Tronox Ltd., 2018, p. 32, 34).

Sheffield Resources Ltd. obtained multiple offtake agreements to account for almost all its zircon and zircon concentrate production during the first 4-year phase of its Thunderbird project. Production of zircon in the first year of production was expected to be about 80,000 t, increasing to about 110,000 t in the fourth year of production. Contingent on financing, Sheffield was expecting to commence production at Thunderbird in 2020 (Sheffield Resources Ltd., 2018, p. 9, 15, 19).

**China.**—As the leading consumer of zirconium mineral concentrates, China imported 1.01 Mt in 2017, a decrease of 4% from 1.05 Mt imported in the previous year (Global Trade Information Services Inc., 2018). During the year, many zircon consumers shut down operations to perform plant modifications to ensure compliance with environmental policies (TZMI Market Update, 2018).

**Kenya.**—Base Resources Ltd. produced 42,200 t of zircon from its Kwale operation in 2017, a decrease of 3% from that of 2016. The Kwale Phase 2 mine project was approved in May and was designed to increase the input of heavy-mineral concentrate into the mineral separation plant to maintain output of finished products despite declining ore grades for the remaining life of the mine (Base Resources Ltd., 2017, 2018).

**Madagascar.**—Base Resources announced an agreement with World Titane Holdings, Ltd. to acquire an initial 85% interest in the Toliara Mineral Sands project. If the project proceeds to mine development, Base Resources planned to acquire the remaining interest in the project. Measured and indicated resources were 612 Mt containing 6.7% heavy minerals. A decision to begin construction was expected in the second half of 2019 (Base Resources Ltd., 2018).

**Mozambique.**—Kenmare Resources plc produced 74,000 t of zircon in 2017, an increase of 9% from that of 2016. Increased production of heavy-mineral concentrates (HMC) was attributed to improved dredge and dry mining techniques (Kenmare Resources plc, 2018, p. 1–2).

**Senegal.**—Mineral Deposits Ltd. produced 81,750 t of zircon, an increase of 55% from that of 2016, owing to the introduction of medium-grade zircon sand to the company’s product line, which added an additional 20,200 t of zircon production in 2017 (TiZir Ltd., 2018).

**South Africa.**—Tronox produced 121,000 t of zircon from its Namakwa Sands operation and 46,000 t of zircon from its KZN Sands operation in South Africa, for a total of 167,000 t, an increase of 2% from that in 2016. Total reported reserves at yearend 2017 for Tronox's operations in South Africa were 864 Mt of ore containing 54.7 Mt of heavy minerals, a 6% decrease from those at yearend 2016 (Tronox Ltd., 2017, p. 36; 2018, p. 33–34).

In 2017, Mineral Commodities Ltd. produced 22,111 t of zircon-rutile concentrate, containing 71% zircon and 18% rutile, at its Tormin Mine in Western Cape Province, a 38% decrease in production from that in 2016. Although the amount of ore processed was greater than that in 2018, the zircon and rutile ore grades decreased from those of 2017. The company's production guidance for 2018 was projected to range from 20,000 to 25,000 t of zircon-rutile concentrate (Mineral Commodities Ltd., 2018, p. 12–13, 19).

**Tanzania.**—In October, Strandline Resources Ltd. announced the maiden ore reserves for its Fungoni heavy-mineral-sands project. Using a cutoff grade of 1.5% heavy minerals, reserves were estimated to contain 3.9% heavy minerals and were estimated to support a mine life of 6.2 years (Strandline Resources Ltd., 2017, p. 1).

## Outlook

TZ Minerals International Pty Ltd., an industry analyst for the zirconium and titanium mineral sands industry, estimated global zircon consumption would increase by 2.8% per year to 2020. Barring new sources coming online, global zircon supplies were expected to be less responsive to demand as existing mines were depleted (Blackwell, 2018, p. 12–13; TZMI Market Update, 2018).

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TABLE 1  
SALIENT U.S. ZIRCONIUM STATISTICS<sup>1</sup>

(Metric tons, gross weight)

	2013	2014	2015	2016	2017
Zircon:					
Production:					
Concentrates	W	W	80,000 <sup>2</sup>	W	80,000 <sup>2</sup>
Milled zircon <sup>e</sup>	48,200	43,300	46,000	49,000	49,900
Exports	29,200	7,460	4,920	5,050	48,400
Imports for consumption <sup>3</sup>	12,400	50,400	32,000	38,400	37,300
Consumption, apparent <sup>4</sup>	W	W	100,000 <sup>2</sup>	W	70,000 <sup>2</sup>
Zirconium oxide: <sup>5</sup>					
Production	NA	NA	NA	NA	NA
Exports	7,000	7,380	5,700	5,420	5,140
Imports for consumption	3,170	4,240	4,140	2,620	3,380
Zirconium, metal, including waste and scrap:					
Production	NA	NA	NA	NA	NA
Exports	1,740	1,450	1,530	1,150	1,600
Imports for consumption	716	1,100	1,320	1,240	1,180
Ferrozirconium:					
Production	NA	NA	NA	NA	NA
Exports	1,960	1,620	973	476	62
Imports for consumption	4	131	158	59	161
Hafnium, unwrought, including powder, imports for consumption	10	21	72	180	113

<sup>e</sup>Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data.

<sup>1</sup>Table includes data available through February 19, 2019. Data are rounded to no more than three significant digits.

<sup>2</sup>Data are rounded to one significant digit to avoid disclosing company proprietary data.

<sup>3</sup>Includes insignificant amounts of baddeleyite.

<sup>4</sup>Defined as production plus imports for consumption minus exports plus or minus Government shipments.

<sup>5</sup>Includes germanium oxides and zirconium dioxides.

TABLE 2  
PUBLISHED YEAREND PRICES OF ZIRCONIUM MATERIALS

(Dollars per metric ton)

Material	2016	2017
Zircon:		
Domestic, standard-grade, bulk	950–1,100	950–1,100
Australian, standard-grade, free on board, bulk	950–1,000	950–1,000
Zirconia, fused, monoclinic, refractory or abrasive	6,000–7,000	6,150–7,150

<sup>1</sup>Table includes data available through February 19, 2019. Data are rounded to no more than three significant digits.

Source: Industrial Minerals.



TABLE 3  
U.S. EXPORTS OF ZIRCONIUM, BY CLASS AND COUNTRY OR LOCALITY<sup>1</sup>

(Gross weight)

Class and country or locality	HTS <sup>2</sup> code	2016		2017	
		Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
<b>Zirconium ores and concentrates:</b>	<b>2615.10.0000</b>				
Belgium		832	\$2,000	911	\$2,130
Brazil		161	478	17	86
Canada		562	1,660	1,460	2,910
Chile		717	1,010	233	408
China		173	382	39,200	29,600
France		453	1,080	957	1,740
Germany		91	239	22	60
India		65	170	215	417
Italy		134	348	135	342
Japan		296	746	692	3,080
Mexico		681	1,730	2,180	3,200
South Africa		7	22	1,440	1,060
United Kingdom		710	1,940	695	1,690
Other		168 <sup>r</sup>	384 <sup>r</sup>	270	669
<b>Total</b>		<b>5,050</b>	<b>12,200</b>	<b>48,400</b>	<b>47,400</b>
<b>Ferrozirconium:</b>	<b>7202.99.1000</b>				
Mexico		74	174	59	124
Venezuela		389	600	--	--
Other		14	65	4	30
<b>Total</b>		<b>476</b>	<b>839</b>	<b>62</b>	<b>154</b>
<b>Unwrought zirconium, including powder:</b>	<b>8109.20.0000</b>				
Germany		20	503	69	1,850
Japan		11	348	4	119
Netherlands		19	434	17	402
Russia		25	1,170	104	4,890
Sweden		61	2,990	49	2,560
United Kingdom		46	1,130	91	3,030
Other		22 <sup>r</sup>	780 <sup>r</sup>	59	2,870
<b>Total</b>		<b>203</b>	<b>7,350</b>	<b>393</b>	<b>15,700</b>
<b>Zirconium waste and scrap:</b>	<b>8109.30.0000</b>				
Belgium		57	1,130	95	869
Canada		57	2,660	49	2,270
Italy		9	170	(3)	3
Japan		13	406	2	71
United Kingdom		16	317	26	423
Other		7	212	61	1,010
<b>Total</b>		<b>160</b>	<b>4,900</b>	<b>234</b>	<b>4,650</b>
<b>Other zirconium:</b>	<b>8109.90.0000</b>				
Argentina		25	2,350	35	3,280
Canada		364	41,100	364	35,300
China		9	720	45	4,090
France		2	239	62	5,930
Germany		18	929	7	746
Japan		33	2,910	60	4,480
Korea, Republic of		153	21,900	199	28,200
Sweden		94	13,000	64	7,840
United Arab Emirates		31	3,510	55	6,210
United Kingdom		38	1,320	66	2,700
Other		21 <sup>r</sup>	2,650 <sup>r</sup>	15	2,430
<b>Total</b>		<b>788</b>	<b>90,600</b>	<b>972</b>	<b>101,000</b>

<sup>r</sup>Revised. -- Zero.

<sup>1</sup>Table includes data available through February 19, 2019. Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Harmonized Tariff Schedule of the United States.

<sup>3</sup>Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 4  
U.S. IMPORTS FOR CONSUMPTION OF ZIRCONIUM AND HAFNIUM, BY CLASS AND COUNTRY OR LOCALITY<sup>1</sup>

(Gross weight)

Class and country or locality	HTS <sup>2</sup> code	2016		2017	
		Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
<b>Zirconium ores and concentrates:</b>	2615.10.0000				
Australia		6,260	\$6,890	7,620	\$7,120
China		358	1,390	265	1,260
Russia		678	2,990	458	2,100
Senegal		11,300	12,300	9,020	10,300
South Africa		19,100	13,000	19,600	15,800
Other		659	1,510	354	1,210
<b>Total</b>		<b>38,400</b>	<b>38,100</b>	<b>37,300</b>	<b>37,800</b>
<b>Ferrozirconium:</b>	7202.99.1000				
Canada		4	46	12	42
China		55	193	149	559
<b>Total</b>		<b>59</b>	<b>240</b>	<b>161</b>	<b>601</b>
<b>Unwrought zirconium, including powder:</b>	8109.20.0000				
China		511	17,000	432	5,220
France		58	2,690	15	657
Germany		199	6,690 <sup>r</sup>	151	5,720
Japan		63	507	58	435
Other		10 <sup>r</sup>	880 <sup>r</sup>	(3)	23
<b>Total</b>		<b>841</b>	<b>27,700</b>	<b>656</b>	<b>12,000</b>
<b>Zirconium waste and scrap:</b>	8109.30.0000				
Australia		135	154	116	133
Canada		12	37	19	33
France		1	16	17	107
Germany		3	54	10	40
Japan		32	253	46	227
Korea, Republic of		13	201	20	229
Other		8	128	15	377
<b>Total</b>		<b>204</b>	<b>844</b>	<b>243</b>	<b>1,150</b>
<b>Other zirconium:</b>	8109.90.0000				
Canada		13	1,500	7	759
France		125	19,000	167	24,900
Germany		29	4,050	59	5,680
Other		28	3,970	48	5,220
<b>Total</b>		<b>195</b>	<b>28,500</b>	<b>282</b>	<b>36,500</b>
<b>Unwrought hafnium, including powder:</b>	8112.92.2000				
China		14	1,920	25	11,100
France		62	9,920	30	8,660
Germany		87	18,700	55	21,500
Other		17 <sup>r</sup>	2,080 <sup>r</sup>	3	785
<b>Total</b>		<b>180</b>	<b>32,600</b>	<b>113</b>	<b>42,100</b>

<sup>r</sup>Revised.

<sup>1</sup>Table includes data available through February 19, 2019. Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Harmonized Tariff Schedule of the United States.

<sup>3</sup>Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 5  
ZIRCONIUM MINERAL CONCENTRATES: WORLD PRODUCTION, BY COUNTRY OR LOCALITY<sup>1</sup>

(Metric tons, gross weight)

Country or locality <sup>2</sup>	2013	2014	2015	2016	2017
Australia	388,000	798,000	601,000 <sup>r</sup>	450,000	505,300
Brazil	24,687 <sup>r</sup>	23,659	21,000 <sup>c</sup>	21,000 <sup>c</sup>	21,000 <sup>c</sup>
China	150,000	150,000	150,000 <sup>r</sup>	140,000 <sup>c</sup>	140,000 <sup>c</sup>
India	40,000	20,626 <sup>r</sup>	18,891 <sup>r</sup>	18,437 <sup>r</sup>	20,000 <sup>c</sup>
Indonesia <sup>c</sup>	49,400 <sup>r</sup>	21,000 <sup>r</sup>	30,900 <sup>r</sup>	34,800 <sup>r</sup>	29,500
Kenya	--	15,004	25,951	39,687	44,438
Madagascar	31,345	27,275	11,879 <sup>r</sup>	12,250 <sup>r</sup>	19,500
Malaysia	379	677	826	800 <sup>c</sup>	1,000 <sup>c</sup>
Mozambique	39,000 <sup>c</sup>	63,100	57,900 <sup>r,c</sup>	68,000 <sup>r</sup>	74,000
Nigeria	2,016 <sup>r</sup>	1,034	960 <sup>r,c</sup>	891 <sup>r</sup>	9,354
Russia <sup>3</sup>	8,504	7,903	8,000 <sup>c</sup>	8,000 <sup>c</sup>	8,000 <sup>c</sup>
Senegal	--	9,040	45,248	52,627	81,749
Sierra Leone	2,951	2,357	1,326 <sup>r</sup>	1,500 <sup>r,c</sup>	3,000
South Africa	224,446	398,101 <sup>r</sup>	330,000 <sup>c</sup>	390,000 <sup>r,c</sup>	377,000
Sri Lanka	2,086 <sup>r</sup>	1,829 <sup>r</sup>	38,135 <sup>r</sup>	24,716 <sup>r</sup>	24,000 <sup>c</sup>
Turkey	-- <sup>r</sup>	1,100	1,500	-- <sup>r,c</sup>	--
Ukraine <sup>c</sup>	41,000	27,000	25,000	22,200	25,000
United States <sup>4</sup>	W	W	80,000	W	80,000
Vietnam <sup>5</sup>	7,600	8,500	3,400	8,700	5,200
Total	1,010,000 <sup>r</sup>	1,580,000 <sup>r</sup>	1,450,000 <sup>r</sup>	1,290,000 <sup>r</sup>	1,470,000

<sup>c</sup>Estimated. <sup>r</sup>Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.

<sup>1</sup>Table includes data available through August 6, 2018. All data are reported unless otherwise noted. Totals and estimated data are rounded to three significant digits; may not add to totals shown.

<sup>2</sup>In addition to the countries and (or) localities listed, small amounts of zirconium mineral concentrates may have been produced in other countries and (or) localities; however, information was not sufficient to make reliable estimates of output.

<sup>3</sup>Production of baddeleyite concentrate averaging 98% ZrO<sub>2</sub>.

<sup>4</sup>Data are rounded to one significant digit to avoid disclosing company proprietary data.

<sup>5</sup>Estimated figures based on Vietnam inferred exports of zirconium ore to China.