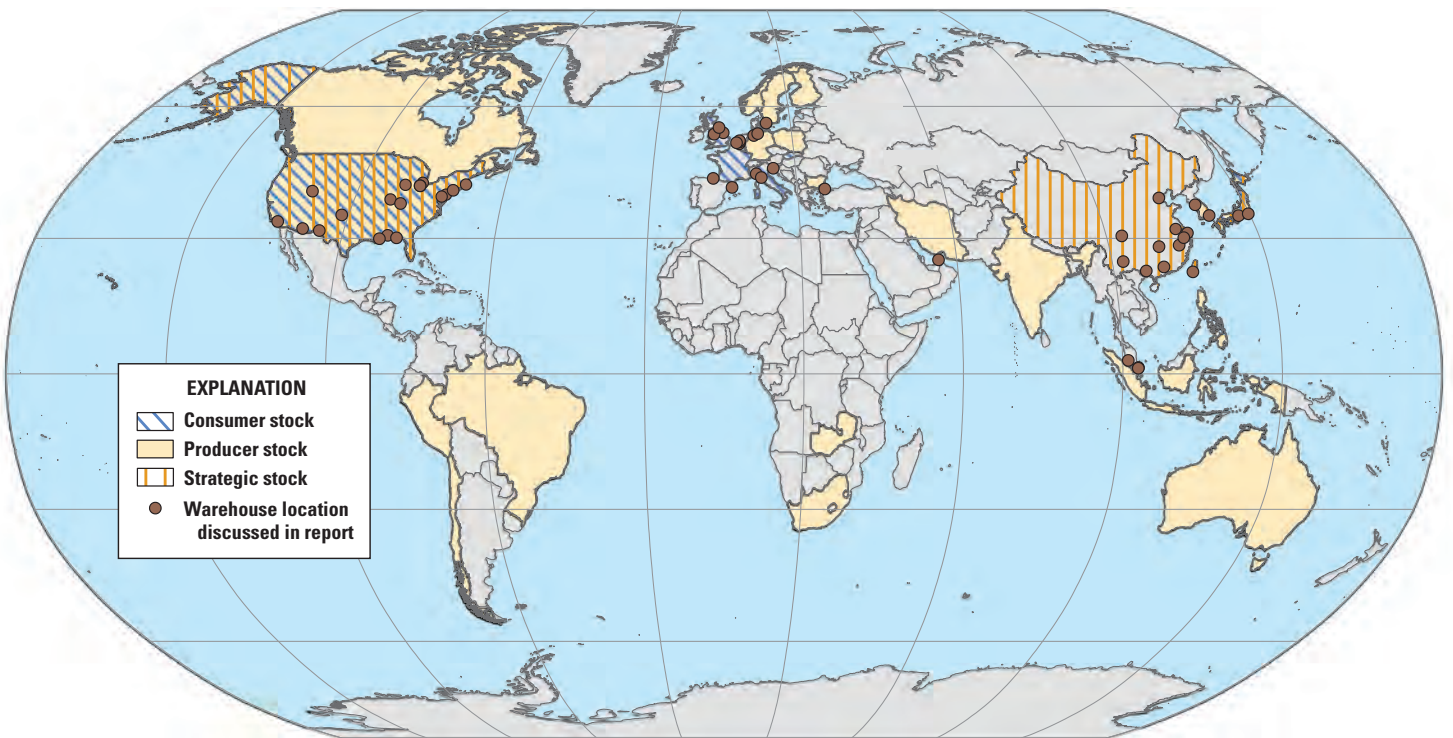


Global Stocks of Selected Mineral-Based Commodities



Scientific Investigations Report 2016–5152

Cover. Global distribution of selected metal stocks. See figure 1 of this report.

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By David R. Wilburn, Donald I. Bleiwas, and Nick A. Karl

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Mass	
metric ton (t)	1.102	ton, short [2,000 pounds]

Datum

Horizontal coordinate information is referenced to the World Geodetic System 1984 (WGS 84).

Abbreviations

COMEX	Commodity Exchange, Inc.
DLA	Defense Logistics Agency (U.S.)
Fanya	Fanya Metal Exchange
ICSG	International Copper Study Group
ILZSG	International Lead and Zinc Study Group
KORES	Korean Resources Corporation
LME	London Metal Exchange
Mt	million metric tons
NDS	National Defense Stockpile (U.S.)
NMIC	National Minerals Information Center (U.S. Geological Survey)
NYMEX	New York Mercantile Exchange, Inc.
PPS	Public Procurement Service (Korea)
SGE	Shanghai Gold Exchange
SHFE	Shanghai Futures Exchange
SRB	State Reserve Bureau (China)
USGS	U.S. Geological Survey

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Introduction

The U.S. Geological Survey, National Minerals Information Center (USGS–NMIC) analyzes mineral and metal supply chains by identifying and describing major components of mineral and material flows from ore extraction, through intermediate forms, to a final product. This report focuses on an important component of the world’s supply chain: the amounts and global distribution of major consumer, producer, and exchange stocks of selected mineral commodities. The terms “stock” and “inventory” are commonly used interchangeably and without distinction by companies, exchanges, journalists, and organizations in journals, press releases, and other forms of data dissemination. In this report, the term “stock” is used instead of “inventory” and refers to accumulations of mined ore, intermediate products, and refined mineral-based commodities that are in a form that meets the agreed-upon specifications of a buyer or processor of intermediate products. These may include certain ores such as bauxite, concentrates, smelter products, and refined metals. Materials sometimes referred to as inventory for accounting purposes, such as ore contained in a deposit or in a leach pile, or materials that need to be further processed before they can be shipped to a consumer, are not considered. Stocks may be held (owned) by consumers, governments, investors, producers, and traders. They may serve as (1) a means to achieve economic, social, and strategic goals through government policies; (2) a secure source of supply to meet demand and to mitigate potential shortages in the supply chain; (3) a hedge to mitigate price volatility; and (4) vehicles for speculative investment.

The paucity and uneven reliability of data for stocks of ores and concentrates and for material held by producers, consumers, and merchants hinder the accurate estimating of the size and distribution of this portion of the supply chain for certain commodities. This paper reviews the more visible stocks held in commodity exchange warehouses distributed throughout the world. The portion of stocks stored outside of traditional commodity exchanges has been referred to as “invisible inventories” (Mikesell, 2011).

The market forces that contribute to changes in stock levels are complex; they may be real or artificial, anticipated or not anticipated, gradual or sudden. Examples of events that may place constraints on the mineral-commodity supply chain

and result in a drawdown of some stocks include (1) natural phenomena, such as earthquakes and weather, that interrupt or reduce production and shipments; (2) economic and technical factors that result in the closure of facilities; (3) increased global demand; (4) local, regional, and political and social issues (environmental concerns, government policies, labor disputes, and military conflicts); and (5) other events that affect cost and availability. Stocks may increase because of concerns over (1) future availability; (2) anticipation of commodity price increases; (3) oversupply through expansions and new entrants; and (4) economic conditions (from local to global levels) that decrease demand. Governments may establish, expand, or reduce stocks based on changes in policies, such as national security concerns. In some cases, the total amount of stock may change little, but is redistributed as stocks move from one location to another or from one stage of the supply chain to another.

The global distribution of the major metal stocks by exchange and type is shown in figure 1. Countries storing strategic mineral stockpiles and countries in which producer and consumer stockpiles are located have been highlighted for locations where data on the level of holdings have been indicated. Locations of stocks held by the largest metal exchanges are also shown.

The estimated size of stock holdings and other details for 2012, 2013, 2014, 2015, and 2016 may be accessed in table 1 by clicking on the link to tables 2–10 provided there. Quantity information reflects data at the beginning of the specified year or as close to the beginning as were publicly available. The data accessed in tables 2–10 do not include all stock data for all mineral commodities. Rather, they show the stocks held by exchanges, governments, producers, consumers, and merchants for a selected number of commodities that are essential for an industrialized country’s economy and national security. These data are updated periodically by the USGS–NMIC.

Some stock data have not been included in the associated tables because they are (1) considered confidential or published in a form from which stocks cannot be estimated on a consistent basis; (2) relatively small and too numerous to list; and (3) considered beyond the scope of this study. Except for a few cases, stocks of gold, silver, and other precious metals held by banks, governments, institutions, and investors

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Base from U.S. Geological Survey Global 30 arc-second elevation data (1996) and from Natural Earth (2014); Robinson projection; World Geodetic System 1984 datum

Figure 1. Global distribution of selected metal stocks by exchange and type.

Table 1. Nonfuel mineral stocks—Index of tables 2–10 by classification.

[Tables 2–10 are in a separate Excel file available for downloading from <https://doi.org/10.3133/sir20165152>. To access an individual table, click on the appropriate yellow tab]

Table number	Stock	Data coverage
Metal Exchange Stocks		
2	CME Group, Inc.	2012–2016
3	Fanya Metal Exchange	2012–2016
4	London Metal Exchange	2012–2016
5	Shanghai Futures Exchange	2012–2016
Strategic Stockpiles		
6	China State Reserve Bureau	2012–2016
7	Japan	2012–2016
8	Republic of Korea	2012–2016
9	United States	2012–2016
Producer, Consumer, and Merchant Stocks		
10	Other stocks	2012–2016

were not included in this study because data that pertain to quantities and locations are often conflicting, incomplete, and (or) unavailable; however, the amount of the sequestered precious metals is considered substantial. For example, a total of nearly 28,000 metric tons (t) of gold was held in central banks at the end of 2014 in the countries having the top twenty central-bank gold holdings (Keiser, 2015). Examples of entities that are involved with the trading of metals (among other commodities) include the Chinese Gold and Silver Exchange Society (trading in precious metals), the Multi Commodity Exchange of India Limited (trading in base and precious metals), and the São Paulo Stock, Mercantile, and Futures Exchange (trading in gold).

Figure 1 and table 1 were developed by the USGS–NMIC from sources of information that include companies, foreign governments, industry analysts, industry associations, international study groups, trade journals, and U.S. Government agencies. The USGS reports total U.S. stocks on a monthly and annual basis for some mineral commodities and for some types of stocks held by governments, producers, major commodity exchanges, and others. These data can be found in USGS Mineral Commodity Summaries, Minerals Yearbooks, and other publications that can be accessed at <http://minerals.usgs.gov/minerals/index.html>.

Metal Exchange Stocks

Although most of the world's mineral commodities are shipped directly from producer to consumer, such as copper which is sold to a consumer following refining, some mineral commodities also are traded globally through metals exchanges. Commodity-exchange certified warehouses are typically located in cities considered to be financial centers or hubs for global commerce with well-established infrastructure. Stocks at trading centers are held primarily as a means to ensure a stable source of supply and for the purpose of financial speculation, but are also sources of material to address increases in demand and to act as a buffer to reduce the volatility of commodity prices. Some of the world's major metal exchanges, based on the tonnage held and their value, are the (1) CME Group, Inc., which operates the Commodity Exchange, Inc. (COMEX) and the New York Mercantile Exchange, Inc. (NYMEX); (2) Fanya Metal Exchange (Fanya); (3) London Metal Exchange (LME); and (4) Shanghai Futures Exchange (SHFE) and the Shanghai Gold Exchange (SGE). Trade and stock data for most of these exchanges are reported daily. The exchanges are described briefly in the following sections.

CME Group, Inc.

The CME Group, Inc. (table 2), headquartered in Chicago, Ill., is a leading options and futures exchange, trading a variety of agricultural, energy, and metal products since 1848. The Group began trading in metals in 1969. The Group processes approximately 3 billion contracts worth about one quadrillion U.S. dollars annually (CME Group, Inc., 2013b). The COMEX and the NYMEX are owned and operated by the CME Group, Inc. The NYMEX is the world's largest energy and metals trading exchange (MarketsWiki Inc., 2014).

The COMEX manages trades in aluminum, copper, gold, and silver and the NYMEX manages the trade of numerous mineral commodities, including diverse types of fuels and nonfuel mineral commodities including aluminum, iron ore, ferrous and nonferrous metals, precious metals, steel, and ferrous scrap. Trading of aluminum on COMEX began on May 6, 2014. The CME Group, Inc., maintains warehouses to stock aluminum, copper, gold, palladium, platinum, and silver in the United States and in Toronto, Canada (storing silver and gold) (CME Group, Inc., 2013b). Approximately 45,000 t of aluminum metal and 63,000 t of copper were reported as COMEX warehouse stocks as of the beginning of 2016 (CME Group, Inc., 2016).

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COMEX aluminum is stored in warehouses located in cities near automotive and industrial manufacturing centers and major ports, including Baltimore, Md.; Chicago, Ill.; Detroit, Mich.; New Orleans, La.; Owensboro, Ky.; and Toledo, Ohio. As of January 2015, about 85 percent of the COMEX aluminum stock was stored in its warehouse facilities in Detroit.

Most of the COMEX copper is stored in warehouses located primarily in cities near U.S. primary copper production. At month-end January 2014, about 79 percent of the 15,000 t of copper stored by the COMEX exchange was stored in warehouses in Tucson, Ariz., and about 17 percent was stored in warehouses in Salt Lake City, Utah. As of January 2015, about 66 percent of 24,000 t of COMEX copper stock was stored in its warehouse facilities in Tucson, and about 29 percent was stored in Salt Lake City. By the end of 2015, however, the total amount of copper stored by COMEX had increased to about 63,000 t, primarily in Tucson, Salt Lake City, and El Paso, Tex.

CME Group, Inc., stores precious metals (gold, palladium, platinum, and silver) at its warehouses near financial centers in the northeastern United States. Warehouses in the New York City metropolitan area contained almost all of the gold, about 94 percent of the palladium, 90 percent of the platinum, and 70 percent of the silver traded on the exchange as of January 2015 (CME Group, Inc., 2015).

Fanya Metal Exchange

The Fanya Metal Exchange (Fanya) (table 3) began transactions in 2011 and reportedly represented over 190,000 members as of February 2015. The exchange traded antimony, bismuth, cobalt, dysprosium, gallium, germanium, indium, selenium, silver, tellurium, terbium, tungsten in the form of ammonium paratungstate, and vanadium, stored in 25 warehouses located in industrial centers of eastern China. According to data published by the exchange, it ranked first in the world in the quantities of bismuth, gallium, germanium, indium, and ammonium paratungstate traded (Fanya Metal Exchange, 2014). Ammonium paratungstate is an intermediate tungsten product. In 2015, Chinese authorities began investigating the Exchange's financial and trading data for illegal practices, which may have exceeded 6 billion U.S. dollars (Stanway, 2015). The audit culminated in the suspension of trading activities (Ruwitch, 2016). For these reasons, reported holdings of the Fanya Metal Exchange should be considered with caution.

Bismuth

Fanya began trading bismuth in March 2013. In April 2014, it was reported that stocks were about 10,000 t (Vulcan, 2016). The exchange reportedly continued to accumulate stocks of bismuth during 2014, reaching a level of about 16,900 t by November 2014, or about 200 percent of the level of world primary production in 2014. Stockpiling on the exchange led to concerns of future availability and a higher price for bismuth. Industry analysts attributed the

sharp increase in price to the rise in stocks held by Fanya that has tightened supply and encouraged consumer buying in anticipation of higher prices (Katrivanos, 2015).

Germanium

Fanya began trading germanium in 2011. In early 2014 it was reported that stocks were approximately 44.5 t, and by November 2014 Fanya reportedly stored more than 91 t, an amount equivalent to 55 percent of world primary germanium production in 2014. This rise in stocks contributed to global price increases by limiting the amount of germanium that was available to consumers (Guberman, 2015).

Indium

In early 2014, it was reported that stocks of indium were estimated at 2,500 t (Vulcan, 2016). The reported stocks of indium held in Fanya warehouses increased significantly to 3,390 t between the end of January 2014 and the end of November 2014, a level equivalent to about 400 percent of 2014 world primary production. Some market participants questioned the magnitude of the increase, considering that the amount was triple China's annual indium production in 2013 and that imports of indium by China in 2014 were relatively low (Tolcin, 2015).

Selenium and Tellurium

Fanya began trading selenium and tellurium in April 2014. In early 2014, it was reported that stocks of selenium and tellurium were estimated to be 20 t and 30 t, respectively (Vulcan, 2016). By November 2014, the reported stocks of selenium reached about 290 t, about 13 percent of reported world primary selenium production in 2014 (as reported by Anderson (2015a), which excludes production from China and the United States). The reported stocks for tellurium reached about 165 t by November 2014, which was more than the combined 2014 primary production of tellurium from Canada, Japan, and Russia (Anderson, 2015b).

London Metal Exchange

The roots of the London Metal Exchange (LME) can be traced to the Royal Exchange of London (United Kingdom), which was founded in 1571 when traders in metal and a range of other commodities began to meet on a regular basis. The LME was formally established in 1877, trading copper and tin. Trading of lead and zinc began in the 1920s, trading of aluminum and nickel began in the 1970s, and trading of cobalt and molybdenum began in 2010. Table 4 shows stocks of these metals. The LME is the largest exchange in the world for nonferrous base metals. They are traded as refined products, as alloys, and in wrought and unwrought forms. Cobalt and molybdenum, which are referred to by the LME as minor metals, are also stored and traded. The exchange began to trade palladium and platinum in December 2014; historical

stock data on these precious metals are not available. The LME does not trade gold and silver. The LME maintains 670 warehouses in 37 locations worldwide (see figure 1). Prior to December 2012, the LME was owned by the banks and brokers that used it. At the end of 2012, the LME was purchased by Hong Kong Exchanges and Clearing Limited, which is also a joint venture partner in the Shanghai Futures Exchange, a growing world trader of ferrous, nonferrous, and precious metals. As of January 2, 2016, LME primary aluminum metal stocks totaled 2.89 million metric tons (Mt) and copper stocks totaled 236,000 t at all warehouses (London Metal Exchange, 2016).

Aluminum

From 2009 through 2013, LME stocks of refined aluminum increased, primarily as a result of the reduction in global consumption associated with the global financial crisis (Georgiou, 2013). Excess material was stored in LME European and U.S. warehouses with offers of low rent and other incentives. At the beginning of 2014, five companies (C. Steinweg Group; Glencore Xstrata PLC; Goldman Sachs Group, Inc.; J.P. Morgan Chase & Co.; and Trafigura Beheer BV) operated 75 percent of LME's licensed warehouses (Shumsky, 2013). As LME aluminum stocks increased and warehouses reached capacity, it became more time-consuming for traders to process transactions and more difficult to transfer material from LME warehouses that were near capacity, because the LME limited the amount of aluminum that could be removed from warehouses each day. This resulted in queue times of up to a year and increased storage costs for consumers, who were forced to pay rent for the additional time while the metal remained in the warehouse (Georgiou, 2013; McGrath and Gara, 2014).

Primary aluminum and aluminum alloy stocks held on the LME declined in 2014 to a level last seen in 2009, for several reasons. The LME proposed rule changes to increase the allowable outflows of aluminum stored in LME-bonded warehouses. A court in the United Kingdom struck down the proposed changes in March 2014, but the ruling was overturned on appeal in October (Bray, 2015). Although the LME proposed in 2014 to limit the maximum waiting time for stocks scheduled for transfer from one location to another to a maximum of 34 days, some banks, hedge funds, and commodity merchants reportedly transferred significant amounts of metals, primarily aluminum and copper, to unregistered warehouses, largely in China, the Netherlands, and the United States (Hodges, 2014; Onstad, 2014; Shumsky, 2013). Although these base-metal stocks may reside in LME warehouses, they are not considered part of the LME system, and records and transactions related to them are kept separate from LME records. By late 2014, several banks signaled their intention to sell their interest in raw materials warehouses to private equity groups; Goldman Sachs Group, Inc., sold its metals warehousing business to Reuben Brothers in December 2014 (Leff, 2014).

Another factor influencing the movement of LME aluminum stocks was an investigation into the alleged use of stockpiled material in China pledged as collateral for multiple loans. This alleged activity prompted some banks and traders to tighten credit and move aluminum to LME warehouses in Europe and copper to LME warehouses in the Republic of Korea and Taiwan having established inventory monitoring protocols (Burns, 2014b; Yap and Curran, 2014).

Copper

From 2010 through 2013, the total copper stocks held at LME warehouses remained at relatively high levels, averaging about 350,000 t (International Copper Study Group, 2014). As with aluminum, LME warehouses attracted metal traders with offers of low rent and other incentives. For example, J.P. Morgan Chase & Co. held about 243,000 t of copper in its warehouses in 2012 (U.S. Senate, 2014). As LME stocks increased, the waiting time for the delivery of stocks from many LME warehouses increased (Day, 2013; Shumsky, 2013). Delays in accessing stored material resulted in increased storage costs, providing incentive for traders to transfer copper from LME warehouses to other less expensive, more accessible locations once they were able to get the metal out of storage. Consequently, the copper stocks at warehouses having the longest delivery waiting times (Antwerp, Belgium; Johor, Malaysia; and New Orleans, La.) declined in 2014. By the end of 2014, reported copper exchange stocks (including COMEX, LME, and SHFE) had declined to their lowest level since 2008 (Teck Resources Limited, 2014, p. 12).

Lead and Zinc

Global refined lead supply in 2013 was derived from secondary supply (about 53 percent), primary supply (about 46 percent), and stocks (about 1 percent). Between 2012 and the beginning of 2014, scrap lead supply was constrained, so global demand for lead was partially met by a drawdown in lead stocks (FastMarkets, 2014c). LME lead stocks decreased 39 percent from about 350,000 t in January 2012 to about 210,000 t in January 2014. LME lead stocks increased modestly in 2014, partially a result of tightened credit conditions in China. Some of the metal that would have been financed in China and normally stored in SHFE or bonded warehouses was shifted to LME warehouses in Europe and Malaysia having ownership certification protocols that satisfied creditors (FastMarkets, 2014d). By January 2016, lead stocks held by the LME had decreased to about 192,000 t (London Metal Exchange, 2016).

LME zinc stocks declined about 43 percent from about 1.2 Mt as of January 2013 to about 463,000 t as of January 2016 for reasons outlined earlier for other base metals. The primary zinc supply deficit was reported to be 68,000 t in 2013 and 60,000 t in early 2014; zinc stocks were likely used as a source to meet demand (FastMarkets, 2014g). LME zinc stocks that were stored in warehouses in Belgium, the Netherlands, and the United States were also likely used in off-market financing deals going to China to act as collateral (FastMarkets, 2014g; Selwyn Resources Limited, 2012).

Nickel

The announcement of a planned export ban on nickel ore by the Indonesian Government in late 2013 led to a global buildup of nickel stocks during 2013 and 2014, leading to a nickel supply surplus for the period (FastMarkets, 2014e; FastMarkets, 2014f; Höhne-Sparborth, 2014). LME nickel warehouse stocks increased 193 percent from about 140,000 t as of January 2013 to more than 410,000 t as of January 2015. LME stocks increased as a result of (1) anticipation of the Indonesia nickel export ban, (2) slowing economies in Europe and China, and (3) the potential for economic sanctions on Russia, a leading nickel producer. LME nickel stocks in warehouses located in Malaysia and Singapore increased because banks tended to favor lending against LME warrants (FastMarkets, 2014f; Iosebashvili, 2014; Selby, 2015). As of January 2016, LME global nickel stocks totaled 441,000 t (London Metal Exchange, 2016).

Shanghai Futures Exchange and the Shanghai Gold Exchange

The Shanghai Futures Exchange (SHFE), headquartered in Shanghai, China, and overseen by the country's State Council, was established in 1992. The SHFE maintains warehoused stocks of aluminum, copper, gold, lead, silver, and zinc; and three steel products (hot-rolled coils, rebar, and wire rod) (Shanghai Futures Exchange, 2013a). Table 5 shows SHFE stocks accessed at the beginning of the years 2012, 2013, 2014, 2015, and 2016. In 2013, the SHFE opened its warehouse network for aluminum and copper to overseas investors (Bloomberg News, 2013). As of the end of 2015, the SHFE was reported to hold aluminum stocks of approximately 297,000 t and copper stocks of 178,000 t (Shanghai Futures Exchange, 2015).

Rapid urbanization and industrialization in China over the past decade has led to a dramatic rise in demand for nonferrous metals, with the resulting increased importance of the SHFE and the increased amount of aluminum and base metal stocks carried by the SHFE to support the growth of Chinese industry. Aluminum and base metal stocks held on the SHFE are stored in warehouses located primarily in the Chinese cities of Shanghai, Guangdong, Jiangsu, and Zhejiang, close to production centers.

Aluminum stocks held by SHFE varied significantly between 2012 and 2015. Aluminum stocks generally increased from 208,000 t as of January 2012 to a peak of about 500,000 t as of April 2013, as a result of the Chinese exchange stockpiling aluminum in anticipation of increased domestic demand. When demand failed to materialize, stocks dropped to about 180,000 t by the end of 2013 (Antaika, 2014). Between December 2013 and May 2014, SHFE aluminum stocks doubled (from about 190,000 t to about 380,000 t) as production cuts at non-Chinese aluminum smelters were announced and the aluminum price began to increase.

The higher aluminum price during the latter half of 2014 encouraged aluminum producers in China to resume output, and Chinese stocks were used to meet domestic demand; by the end of 2014, SHFE stock levels were at a level only slightly above the 2013 level (FastMarkets, 2014a,b; Capital Economics, 2015). A similar pattern can be shown for copper stocks on the SHFE. Copper stocks on the SHFE increased from about 126,000 t in January 2014 to about 220,000 t in March 2014, then decreased to a level of about 112,000 t as of January 2015 (Hellenic Shipping News Worldwide, 2014; International Copper Study Group, 2014; Capital Economics, 2015). Lead and zinc stocks on the SHFE ended 2014 lower than they were at the beginning of 2014. By the end of 2015, aluminum, copper, and zinc stocks held by the SHFE had increased to about 297,000 t, 178,000 t, and 200,000 t, respectively (Shanghai Futures Exchange, 2015).

Shanghai is also the location of the Shanghai Gold Exchange (SGE), which initiated trading in 2002 (Shanghai Gold Exchange, 2014). The SGE organizes physical trades of precious metals and stores gold and silver in 36 Chinese cities in 58 vaults (O'Byrne, 2014). In early 2015, the SGE was the world's largest physical gold exchange, estimated to hold as much as 11,000 t of the metal (Jansen, 2015; World Gold Council, 2015). In contrast, the trades of precious metals on the COMEX have significantly greater value, but the trades are primarily based on the buying and selling of futures contracts, not physical metal (Cammarosano, 2015).

Strategic Stockpiles

Governments of at least four countries (China, Japan, the Republic of Korea, and the United States), are known to publish information related to stockpiles of selected metals, primarily held for strategic reasons, but for other reasons as well. For example, China's State Reserve Bureau (SRB), a Government-controlled entity, has purchased mineral commodities as a form of subsidy to support industry and employment during periods of economic slowdowns (Hoshion News, 2014; Wong, 2014). Information on Chinese Government stocks is limited. Information on Japanese, Korean, and U.S. stockpiles is reported through official sources (Graedel, 2010; Risk & Policy Analysts Ltd., 2012).

Russia is also reported to host strategic stockpiles of various metals, but data on locations and quantities have not been released.

China's official stockpiles have reportedly accumulated between 290,000 t and 2 Mt of aluminum and substantial amounts of other mineral commodities. China's SRB is reported to have accumulated stocks of selected mineral commodities for strategic purposes including aluminum, antimony, cadmium, cobalt, gallium, germanium, indium, molybdenum, rare-earth elements, tantalum, tin, tungsten, and zirconium (Risk & Policy Analysts Ltd., 2012). The SRB is reported to have purchased cobalt metal, molybdenum oxide

concentrate, rare-earth element concentrates, and tungsten concentrate in 2014. Because China does not publish details of its metal stockpiles, it may be that stocks of the minor metals are included in the stocks reported by the Fanya Metal Exchange (Yam and Bhal, 2014a). The SRB continued to purchase large quantities of selected metals during 2014. Various traders have estimated that the SRB purchased up to 500,000 t of copper in early 2014 and announced plans to purchase 100,000 to 150,000 t of nickel at relatively low international prices. The SRB also announced plans to sell about 200,000 t of old copper stocks in the domestic market in 2014 (Yam, 2014). Various reports suggest that the Chinese strategic stockpile may have contained as much as 1.5 Mt of copper at the end of 2014 (SNL Metals & Mining, 2015; Yam, 2014) (table 6).

The Japanese Government typically tries to maintain a level of 60 days of domestic consumption in its strategic stockpile, consisting of 42 days in Government stocks and 18 days in private-sector stocks. Stocks are reported to be maintained for chromium, cobalt, gallium, indium, manganese, molybdenum, nickel, tungsten, and vanadium (Graedel, 2010; Risk & Policy Analysts Ltd., 2012) (table 7).

Strategic stocks of some metals are held by the Korean Resources Corporation (KORES) with a goal to store an amount that is equivalent to 60 days of imports. KORES holds stocks for antimony, chromium, gallium, molybdenum, niobium, rare-earth elements, selenium, titanium, and tungsten in various forms as reported in table 8. Stocks for selected base metals are also held by the Korean Public Procurement Service (PPS). The PPS is believed to hold stocks for aluminum, cobalt, copper, indium, lead, lithium, manganese, nickel, silicon, tin, vanadium, and zinc, and announced plans to stockpile bismuth, germanium, magnesium, strontium, and tantalum (Graedel, 2010; Risk & Policy Analysts Ltd., 2012). Quantities, however, are not available.

The U.S. Defense Logistics Agency (DLA) maintains a National Defense Stockpile (NDS) of selected mineral commodities and materials, intended to support defense production and essential civilian needs in time of national emergency. The DLA stores various forms of 19 mineral commodities at nine locations throughout the United States. Since its inception, just prior to World War II, the NDS has contained a wide variety of mineral-based materials in various forms. These have included metallic and nonmetallic ores, ferrous and nonferrous metals and their alloys, and precious metals. Reports by the U.S. Department of Defense, published in 2015 and 2016, contain data pertaining to the amounts, values, and characteristics of the materials stockpiled in the NDS (Defense Logistics Agency, 2015, 2016; Comptroller General of the United States, 1979). DLA stock levels of metals and mineral products are reported in table 9.

In fiscal year 2014, the DLA sold \$68 million (about 4 percent of the stockpile value) of excess mineral materials from the NDS; at the end of the year, the remaining stockpile was valued at \$1.5 billion (U.S. Geological Survey, 2015).

Producer, Consumer, and Merchant Stocks

A significant quantity of mineral commodities is stored by producers and consumers near the source of supply or near the manufacturing site for the purpose of maintaining and ensuring supply to their customers, such as iron ore for steelmaking. Stocks are generally equivalent to 30 to 90 days of demand. Merchants and traders, which include scrap dealers, also maintain stocks. These non-exchange stocks are held in warehouses commonly located in highly industrialized countries in anticipation of short-term customer demand and are supplied to customers as needed. Statistical data related to the amount, location, and nature of these producer, consumer, and merchant stocks are reported on a limited basis in industry-related publications and by some international organizations and large producers. Statistical data published by these groups and examples of producer and consumer stocks for several commodities are included in table 10. China maintains the largest producer and consumer stocks in the world, but data on Chinese producer and consumer stocks are limited.

Stock estimates published by organizations, such as international study groups for copper, lead and zinc, and nickel, and trade organizations such as the International Aluminium Institute, are usually limited to data from member companies and countries. The International Aluminium Institute reported the global producer stocks for unwrought aluminum metal at the end of 2014 at 1.4 Mt and the producer stocks for total aluminum (unwrought aluminum, unprocessed scrap, metal in process, and semi-fabricated mill products) at 2.5 Mt (International Aluminium Institute, 2015). The International Copper Study Group (ICSG) reported total global refined copper stocks for producers, consumers, and merchants (excluding bonded merchants) as of December 31, 2015, at 981,000 t (International Copper Study Group, 2015b). The International Lead and Zinc Study Group (ILZSG) reported global producer and consumer stocks for refined lead as of December 31, 2015, at 290,700 t (International Lead and Zinc Study Group, 2015). The ILZSG also reported global producer, consumer, and merchant refined zinc stocks as of December 31, 2015, at 573,600 t (International Lead and Zinc Study Group, 2015). Global producer and consumer stocks for Class 1 refined nickel (having a nickel content greater than or equal to 99 percent) as reported by the International Nickel Study Group (2016) as of December 31, 2015, were 55,000 t of contained nickel. Global producer stocks for Class 2 charge nickel (having a nickel content less than 99 percent), such as nickel oxide sinter and nickel chemicals, as of December 31, 2015, were 24,100 t (International Nickel Study Group, 2016). Class 2 stocks are not carried by the LME (Peter Kuck, USGS nickel specialist, oral commun., December 4, 2014).

Estimated stocks of imported metallurgical bauxite and iron ore at Chinese ports to supply a portion of the country's

aluminum and steel industry are regularly published. In late 2015, approximately 20 Mt of bauxite ore and 94 Mt of iron ore resided at Chinese ports (Mok, 2016; Mysteel.net, 2016). In response to the export ban on unrefined nickel products from Indonesia, China increased its stocks of lateritic nickel ore from Australia, the Philippines, and Vietnam. The stock level of nickel at Chinese ports increased from about 13.5 Mt as of May 2014, then decreased to 10.7 Mt as of December 2015, but growing demand for nickel resulted in a decrease in Chinese port stocks of nickel from midyear levels by the end of 2014 (Shanghai Metal Exchange Market, 2015).

Unregistered and Bonded Warehouses

Banks, hedge funds, and commodity merchants are reported to have put millions of tons of base metals in a system of unregistered warehouses, primarily in China, the Netherlands, and the United States (Shumsky, 2013). Although these metals may reside in LME warehouses, this material is not considered to be part of the LME system. At the end of 2013, about 7 to 10 Mt of aluminum was estimated to be in these warehouses, compared to the 5.4 Mt that was stored in LME warehouses. Storage fees at these warehouses may be lower than storage fees at LME warehouses by up to a factor of 10 (Shumsky, 2013; Hodges, 2014). Accurate stock figures for some of the mineral commodities stored in these warehouses are difficult to acquire, and estimates vary substantially. The paucity of data makes it difficult to determine their influence on the global supply chain.

According to the ICSG, between June 2013 and February 2014, approximately 383,000 t of refined copper was removed from LME warehouses and 53,000 t of copper was removed from COMEX warehouses (International Copper Study Group, 2014). Approximately 250,000 t of this copper was reportedly transferred to bonded warehouses in China and another 12,000 t was transferred to SHFE, and the balance was likely sold to consumers or purchased by the Chinese SRB. Estimates for the amount of copper held in Chinese bonded warehouses at the end of 2014 ranged from approximately 500,000 t to as much as 1,000,000 t, more than the quantity of copper stocks held by all three major exchanges (Home, 2014a,b; Keohane, 2014; Risopatron, 2014). As of October 2014, Chinese bonded warehouses reportedly held 618,000 t of aluminum, 209,000 t of zinc, and 110,000 t of lead (Shanghai Metal Exchange Market, 2015).

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