

INTRODUCTION

Zinc has been used in brass and bronze since ancient times. The metal was produced in its elemental form much later. In the 20th century, the invention of froth flotation spurred zinc production and the development of galvanizing increased its use.

Uses

Zinc is the third most used nonferrous metal, after aluminum and copper. Most primary zinc is recovered as slab. The largest use of slab zinc is for galvanizing (and electrogalvanizing), an application which accounted for 51 percent of U.S. consumption in 1988. Other uses include zinc-based die-cast alloys (23 percent), brass alloys (13 percent), chemicals, and dusts. The galvanized products are used in the steel, automobile, and construction industries. No substitute for galvanizing exists for protecting large tonnage iron and steel products from corrosion.¹ Secondary zinc, most of which comes from new scrap, is used to produce brass and bronze (46 percent of 1988 domestic use), slab zinc (26 percent), chemicals (18 percent), and dusts (7 percent).

Production Methods and Technologies

Zinc is produced mostly from the sulfide ores: sphalerite (ZnS) and marmatite ([Zn,Fe]S). These ores, also known as zinc blende, are commonly associated with galena, the principal lead ore. Over 80 percent of nonsocialist world (NSW) zinc mines are underground operations. After mining, the ore is crushed, ground and subjected to several froth flotation steps to remove the lead, iron, and gangue (waste rock). The resulting zinc concentrates typi-

cally contain 50 to 64 percent zinc. These beneficiation steps are performed at the minesite.³

At the smelter/refinery, zinc is produced by one of several processes that smelt and refine the metal simultaneously. Regardless of the process, the concentrates are first roasted into zinc-oxide materials. In roasting, the concentrates are burned in the presence of oxygen (usually from air) thus forming crude zinc oxides and gaseous sulfur dioxide. Most modern roasters are fluid-bed reactors.

The crude oxide is then smelted/refined by electrolytic or pyrometallurgical methods. The electrolytic process is the most common method, accounting for about 80 percent of NSW smelting/refining capacity. In the first step of this process, the crude oxide feed is leached with sulfuric acid to produce a zinc sulfate solution. This is then purified and pumped into electrolytic cells. The cells use lead-silver anodes and aluminum cathodes. Upon application of the current, the zinc in the solution is reduced and deposited on the cathode. The cathode is stripped periodically and the zinc metal is cast into ingots. Virtually all impurities remaining from the preparation processes are eliminated. Electrolytic zinc needs no further refining. Purity normally exceeds 99.95 percent and can possibly be 99.995 percent or better.

In the pyrometallurgical production methods, the crude zinc oxides from the roaster are first sintered in a Dwight-Lloyd moving grate machine or a rotary kiln to yield a homogeneous feed. The sinter is then heated to above 1,832 °F (a temperature at which zinc is vapor) in the presence of a reducing agent (chiefly carbon monoxide) in one of four types of furnaces.⁴ This reduces and vaporizes, the zinc, which is then collected in a condensation vessel.

¹James H. Jolly, "Zinc," *Minerals Yearbook*, vol. 1, 1988 ed. (Washington, DC U.S. Department of the Interior, Bureau of Mines, 1990).

WariH.Cotterill, "Zinc Metallurgy," *McGraw-Hill Encyclopedia on Science and Technology* (New York, NY: McGraw-Hill, 1987). James H. Jolly, "Zinc," *Mineral Facts and Problems*, 1985 ed. (Washington, DC: U.S. Department of the Interior, Bureau of Mines, 1985).

³Zinc oxide ores, which have declined in importance since the development of the froth flotation process, and other zinc bearing secondary materials are generally not concentrated at the minesite. They are pyroconcentrated at the smelter in a Waelz rotary kiln or by slag fuming.

⁴The four pyrometallurgical zinc production technologies are: the horizontal (Belgian) retort, the vertical (New Jersey) retort, the electrothermic (St. Joseph) retort, and the blast (Imperial Smelting) furnace. The Imperial Smelting Process (ISP), which is used primarily in Europe, Japan and Australia, is the most common. It is basically a lead blast furnace with a zinc recovery system added. It can treat mixed zinc and lead concentrates, low-grade concentrates, and oxide concentrates. The Belgian process, the oldest, is a batch method. The New Jersey and St. Joseph methods are continuous processes. A fifth pyrometallurgical technology, the Soviet-developed Kivcet process, has found limited use. It can process lead-zinc concentrates directly, thus eliminating the need for sintering.

Most of the impurities are eliminated to the furnace residues. Zinc recovered by any of the pyrometallurgical methods is less than 99 percent pure. The quality is adequate for hot-dip and continuous line galvanizing, and for some brass uses. However, for die casting, the zinc must be further refined. Fractional distillation is the most common method of upgrading the lower purity zinc.

THE 1980s

The U.S. zinc market started the 1980s on a mixed note (see figures 5-1 and 5-2). Prices (averaging \$0.37/lb) in 1980 were slightly higher than those of the late 1970s. In 1980, domestic mine production (349,000 tonnes) was higher than it had been in the two previous years, but below what it had been for most of the 1970s. Slab zinc production (370,000 tonnes) was much lower in 1980 than it had been in previous years.

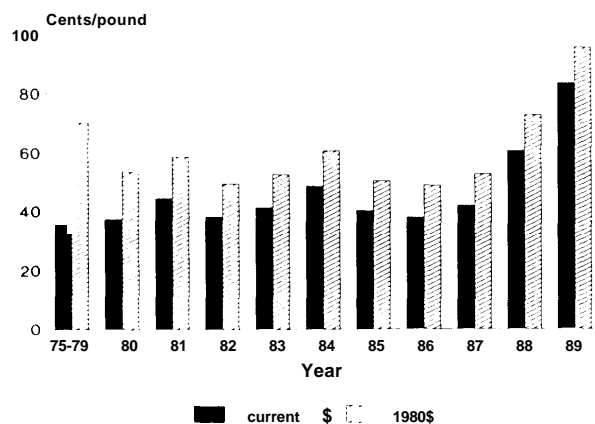
The price of zinc, unlike those of the other metals in this study, remained above its 1980 level for the entire decade. The greatest increase came in the late 1980s, when zinc prices rose from \$0.42/lb in 1987 to \$0.83/lb in 1989. U.S. mine production fell during 1980-86. It rose in the later years, but ended the decade down 20 percent. Primary refined production, which declined sharply in 1982, finished the decade down 26 percent.

Secondary zinc increased its importance in the market during the 1980s. In 1989, it accounted for 23 percent of slab zinc production in the United States.⁵ Most secondary material is recovered as products other than slab zinc. The extensive use of zinc in galvanizing and other dissipative uses limits the potential for increased recycling. New scrap is principally zinc alloy and brass from manufacturing operations.

U.S. slab zinc consumption rose throughout most of the 1980s. Its only large decline came during the recession in 1982. Consumption in 1989 was 21 percent greater than that in 1980 (but only 8 percent greater than the 1975-79 average). Most zinc used in the United States is imported. In 1989, total U.S. slab production (primary and scrap-based) amounted to only 34 percent of domestic consumption.

⁵These figures represent the slab zinc recovered from both new and old scrap. Old scrap comes from discarded products, new scrap is waste from fabricating and other manufacturing processes. In 1988, 342,000 tonnes of secondary zinc were recovered from old scrap (97,000 tonnes) and new scrap (245,000 tonnes), and recovered as slab zinc (89,000 tonnes) and other products (254,000 tonnes). James H. Jolly, "Zinc," *Minerals Yearbook*, vol. I, 1988 cd. (Washington, DC: U.S. Department of the Interior, Bureau of Mines, 1990).

Figure 5-1—Zinc Prices, 1975-89



NOTE: U.S. producers price- High Grade zinc delivered. Prices inconstant 1980 dollars were calculated using producer price index. Bars labeled 75-79 represent averages for the period 1975-79.

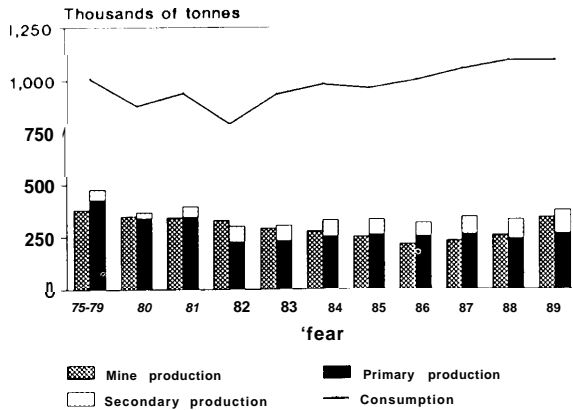
SOURCE: U.S. Bureau of Mines.

In the nonsocialist world, zinc output and use rose fairly steadily during the decade (see figure 5-3). NSW production and consumption in 1988 were both around 5.2 million tonnes, which represented a 17 percent increase over the 1980 levels.

The openings, closings, and ownership changes that occurred in the U.S. primary zinc industry during the 1980s are profiled in table 5-1. Two new zinc mine (Pierrepoint and Ward Mountain) and two zinc-producing precious metals mines (Greens Creek and Montana Tunnels) opened during the decade. In addition, zinc is recovered from the West Fork lead mine which opened in 1985. The Butte Hill zinc-lead-silver mine, which had been closed since the early 1970s, reopened in 1990. The Red Dog zinc-lead mine is slated to begin full production in 1990. Five zinc mines were permanently closed in the 1980s. In the processing sector, three smelter/refineries were closed permanently and no new ones opened. During 1980-88, U.S. primary slab zinc capacity declined 44 percent to 320,000 tonnes.

Acec-Union Miniere (based in Belgium) increased its position in the U.S. zinc industry in the 1980s. It acquired full control of Jersey Miniere in 1984 and purchased the USX zinc facilities in 1989. Horsehead Industries entered the industry by purchasing zinc facilities from New Jersey Zinc and

Figure 5-2--U.S. Slab Zinc Production and Consumption, 1975-89



NOTE: Secondary production is refined metal recovered from old and new scrap. Bars labeled 75-79 represent averages for the period 1975-79.

SOURCE: *Metal Statistics*, Metallgesellschaft Aktiengesellschaft.

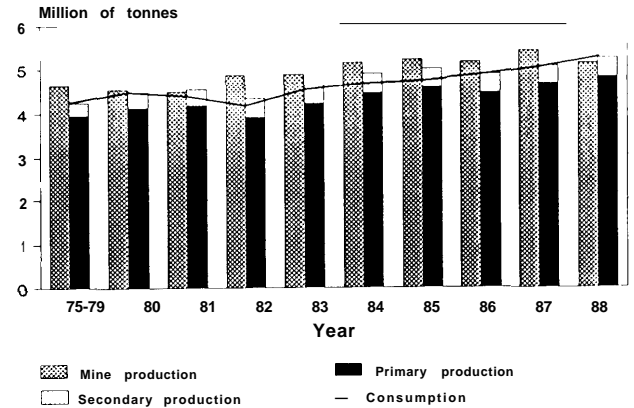
Fluor (St. Joe). It merged them into a venture called the Zinc Corporation of America (ZCA). Other new zinc mining companies include Doe Run, Montana Tunnels, Greens Creek, Washington Mining, Bunker Hill Mining, Star-Phoenix Mining, New Butte Mining, Alta Gold, and Cominco-NANA. Big River is the only new zinc processor. It purchased the Sauget, Illinois facility from Amax in 1988. Five companies (New Jersey Zinc, USX, Bunker Hill, Amax, and Standard Metals) left the U.S. industry during the 1980s.

PRODUCER PROFILES, 1990

Most zinc is produced in industrialized countries (see figure 5-4). Compared with copper, very little zinc capacity is government-owned. Developed countries account for about 70 percent of mine capacity and even greater percentages of primary smelter/refinery capacity.⁶ Canada is the largest producer in both the mining and processing sectors. Australia is a large mine producer and a medium-sized processor. Peru and Mexico have large mine production, but little processing capacity. Japan and European countries are large refined zinc producers. The United States has a medium-sized zinc industry.

In most parts of the world, zinc and lead are mined and processed together. The situation is somewhat

Figure 5-3--NSW Slab Zinc Production and Consumption, 1975-88



NOTE: Secondary production is refined metal recovered from old and new scrap. Bars labeled 75-79 represent averages for the period 1975-79.

SOURCE: *Metal Statistics*, Metallgesellschaft Aktiengesellschaft.

different in the United States. The U.S. zinc and lead industries are relatively separate, though there are some domestic mines that produce both metals.

United States

The United States is a medium-sized zinc producer. It ranks sixth in the NSW in mine output and eighth in primary metal production. The country was a net importer of zinc concentrates during 1983-88, but a net exporter in 1989. For refined (slab) zinc, the United States is dependent on imports for about two-thirds of its needs. The major suppliers during 1985-88 were Canada (accounting for 56 percent of imports), Mexico, and Spain. Slab exports are small.

About half of U.S. zinc mine production comes from Tennessee. The other major mining States are Missouri, Colorado, Alaska, Idaho, Montana, New York, and Nevada. Processing facilities are located in Tennessee, Pennsylvania, Oklahoma, and Illinois.

Asarco

Asarco is the largest U.S. zinc mining company (see figure 5-5). Most of its production is from its four mines in eastern Tennessee, but some also comes from its Missouri lead mines and its partially owned Leadville, Colorado operation. These facilities accounted for 37 percent of U.S. zinc mine

⁶In this report, little distinction is made between the smelting and refining sectors of the zinc industry. One or the other, but not both, of the processing steps is usually sufficient to produce marketable zinc.

Table 5-I—Profile of U.S. Primary Zinc Production Industry, 1980 and 1990

	1980	1990	
Major mines:			
Zinc mines:			
Ward Mountain, NV	—	Aita Gold	Opened 1990
Young, TN	Asarco	Asarco	
Immel, TN	Asarco	Asarco	
New Market, TN	Asarco	Asarco	
Coy, TN	Asarco	Asarco	
Beaver Creek, TN	New Jersey Zinc ^a	Asarco	Sold to Inspiration 1983, Asarco 1988; merged with Young, TN mine
Jefferson City, TN	New Jersey Zinc ^a	—	Closed 1983; sold to Inspiration 1983, Asarco 1988
Elmwood-Gordonsville, TN	Jersey Miniere ^{a,b}	Jersey Miniere ^c	Gordonsville opened 1982; Note 1
Freidensville, PA	New Jersey Zinc ^a	—	Closed 1983
Austinville/Ivanhoe, VA	New Jersey Zinc ^a	—	Closed 1981
Idol, TN	New Jersey Zinc ^a	—	Closed 1981; sold to Inspiration 1983
Zinc Mine Works, TN	US Steel (USX)	Union Zinc ^d	Sold to Union Zinc 1989
Pierrepont, NY	—	ZCA ^d	Opened 1982; owned by Fluor (St. Joe); Notes 2&3
Balmat, NY	St. Joe	ZCA ^d	Notes 2&3
Sterling, NJ	New Jersey Zinc ^a	—	Closed 1985; Notes 4&3
Mixed lead-zinc mines:			
Leadville, CO	Asarco-Newmon ^e	Asarco-Newmon ^e	
Bunker Hill, ID	Bunker Hill ^f	Bunker Hill Mining	Closed 1981; Note 5; reopened 1988
Red Dog, AK	—	Cominco-NANA ^g	Opened 1990
Butte Hill, MT	—	New Butte Mining	Closed since early -1970s; reopened 1990
Star-Morning Unit, ID	Bunker Hill-Hecla ^h	Star-Phoenix Mining	Closed 1982; Star-Phoenix signed 10 year lease-purchaser agreement 1989; reopened 1990
Lead mines:			
West Fork, MO	—	Asarco	Opened 1985
Magmont, MO	Cominco-Dresser ⁱ	Cominco-Dresser ⁱ	
Buick, MO	Amax-Homestake ^j	Doe Run ^k	Amax share sold to Homestake 1986; Note 6
Precious metals mines:			
Greens Creek, AK	—	Greens Creek ^l	Opened 1989; Note 7
Lucky Friday, ID	Hecla	Hecla	
Montana Tunnels, MT	—	Montana Tunnels ^m	Opened 1987; Note 8
Sunny side, CO	Standard Metals	Washington Mining ⁿ	Sold to Echo Bay 1985; Note 9
Smelter/refineries:			
Corpus Christi, TX	Asarco	—	Closed 1985 (indefinite), 1988 (permanent)
Sauget, IL	Amax	Big River	Sold to Big River 1988
Kellogg, ID	Bunker Hill ^f	—	Closed 1981 (indefinite), 1985 (permanent)
Clarksville, TN	Jersey Miniere ^{a,b}	Jersey Miniere ^c	Note 1; Expanded 1988
Monaca, PA	St. Joe	ZCA ^d	Expanded 1981-83; Notes 2&3
Bartlesville, OK	National Zinc	ZCA ^d	Sold to Continental 1983, Fluor (St. Joe) 1984; Note 3
Palmerton, PA	New Jersey Zinc ^a	ZCA ^d	Smelter closed 1980; Notes 4&3; plant makes zinc oxides, dusts, and powders

^aNew Jersey Zinc was a subsidiary of Gulf and Western Industries Inc.

^bJ.S. Miniere was a subsidiary of New Jersey Zinc and Union Miniere.

^cJersey Miniere is a subsidiary of Union Zinc. Union Zinc is a subsidiary of

AceC-Union Miniere.

^dZinc Corp. of America (ZCA) is a subsidiary of Horsehead Industries.

^eAsarco and Newmont each own 50 percent of the Leadville mine. Asarco

is the operator.

^fBunker Hill was a subsidiary of Gulf Resources and Chemical Corp.

^gCominco-Alaska developed and operates the Red Dog mine. NANA owns the mineral rights.

^hThe Star Morning Unit was owned 70% by Bunker Hill and 30% by Hecla. It was operated by Hecla.

ⁱCominco and Dresser Industries each own 50 percent of the Magmont mine. Cominco is the operator.

^jAmax and Homestake each owned 50 percent of the Buick mine.

^kDoe Run is a subsidiary of Fluor.

^lGreens Creek mine is a joint venture of RTZ, Hecla, Exalax Resources

Corp. (a subsidiary of Mitsubishi), and CSX Oil & Gas Corp.

^mMontana Tunnels is a subsidiary of Pegasus Gold.

ⁿSunnyside Mine is a joint venture of Alta Gold (owned by Silver King and Pacific Silver), Washington Mining, and Echo Bay. Washington Mining is the operator.

¹New Jersey Zinc share of Jersey Miniere sold to Union Miniere 1984.

²St. Joe acquired by Fluor 1981.

³Zinc assets of Fluor (St. Joe) sold to Horsehead Industries and merged with New Jersey Zinc Co. Inc. (NJZI) to form Zinc Corp. of America (ZCA) 1987.

⁴Sold to Horsehead Industries investment group and operated as New Jersey Zinc Co. Inc. (NJZI) 1981.

⁵Bunker Hill, ID mine was sold to Bunker Hill Ltd. partnership 1982. Bunker Hill Mining created in public spinoff 1988.

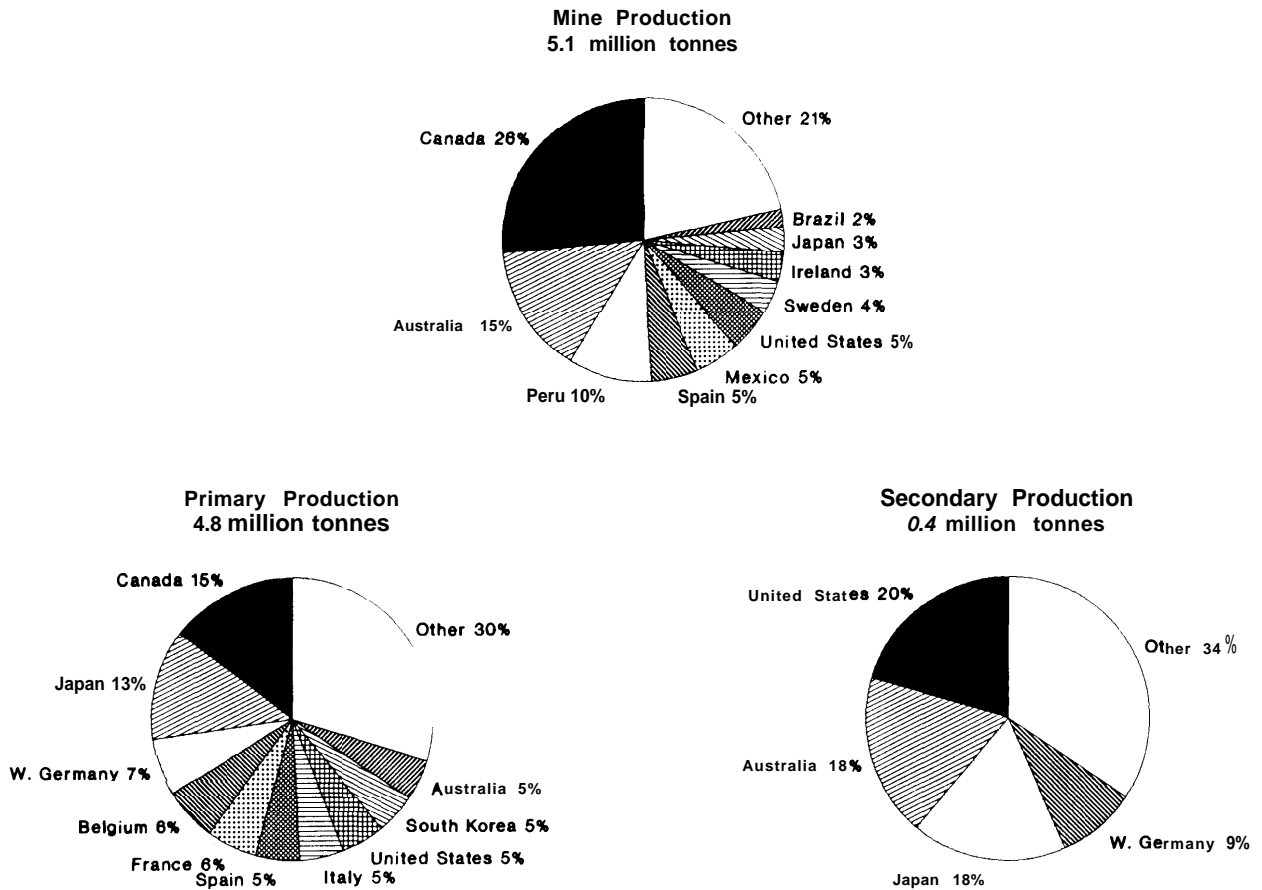
⁶Lead assets of Fluor (St. Joe) and Homestake merged to form Doe Run 1986. Doe Run was owned 57.5% by Fluor and 42.5% by Homestake 1986-90. Fluor became sole owner by purchasing Homestake's share 1990.

⁷Exploration and development led by Noranda 1981-86, British Petroleum 1986-1 989; Hecla became a minority partner 1987; RTZ became majority holder 1988.

⁸Owned by U.S. Minerals Exploration (USMX); explored by Placer Development 1981-82, Centennial Minerals 1983-85; Centennial Minerals acquired by Pegasus Gold 1985; USMX share sold to Pegasus Gokt 1987.

⁹Echo Bay and Alta Gold (owned by Silver King and Pacific Silver) formed the Alta Bay Venture in June 1988. Alta Bay is 60% owned by Alta Gold and 40% owned by Echo Bay. Echo Bay contributed the Sunnyside, CO mine and other properties to the venture. Washington Mining (which owns the property) became a 35% partner in November 1988 and the mine operator in January 1989. Alta Bay owns the remaining 650/..

Figure 5-4--NSW Zinc Production, Country Profile, 1988



NOTE: Secondary production is refined metal recovered from old and new scrap.
SOURCE: *Metal Statistics*, Metallgesellschaft Aktiengesellschaft.

output in 1988.⁷ The company sells and/or tolls most of its zinc concentrate production. Asarco no longer has slab zinc processing capacity. It converted its Corpus Christi, Texas refinery to a hazardous waste processing facility in 1988. It does, however, operate a zinc-oxide plant at Hillsboro, Illinois.

Jersey Miniere

Jersey Miniere is the second largest domestic zinc producer. The company accounted for an estimated 20 percent of U.S. mine production and 29 percent of refinery capacity in 1988. Jersey Miniere's

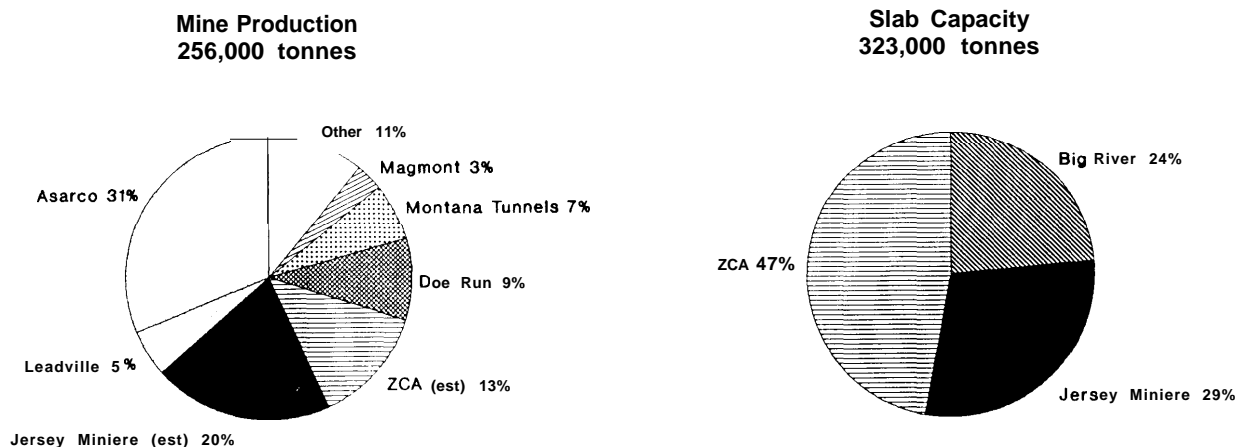
operation is fully integrated. It has a mine and a smelter/refinery in central Tennessee. In addition, its parent Union Zinc, purchased The Zinc Mine Works in Jefferson City, Tennessee from USX in 1989. With this additional capacity, the company's U.S. mines can provide two-thirds of the concentrate feed needed by its Clarksville refinery.⁸

Jersey Miniere is owned by Union Zinc, a subsidiary of Belgium-based Acec-Union Miniere (the nonferrous and nonmetallic minerals unit of Societe Generale de Belgique). Acec-Union Miniere

⁷This figure includes entire production of the Leadville mine.

⁸U.S. Department of the Interior, Bureau of Mines, *Minerals and Materials* (Washington, DC: June/July 1989).

Figure 5-5—U.S. Zinc Industry, Company Profile, 1988



NOTE: Mine production figures for Jersey Miniere and ZCA are OTA estimates. Jersey Miniere's mine production includes that of the USX mine purchased in 1989. About one-third of ZCA's slab capacity is used to process secondary zinc.

SOURCES: *Minerals Yearbook* (various issues), U.S. Bureau of Mines; *Non-Ferrous Metal Data 1988*, American Bureau of Metal Statistics Inc.; company annual reports.

is one of the world's largest zinc and lead producers. Its other lead and zinc interests include Metallurgie Hoboken-Overpelt (MHO), Vieille-Montagne, and Asturienne. Acec-Union Miniere began reorganizing its operating units in early 1990.

Zinc Corporation of America

Zinc Corporation of America (ZCA) is also a fully integrated producer. It accounted for an estimated 13 percent of the country's mine production and almost one-half of the refinery capacity in 1988. ZCA has two mines in New York, a smelter/refinery in Pennsylvania, and a refinery in Oklahoma. It also processes steelmaking dusts into zinc at a plant in Pennsylvania.

ZCA, a subsidiary of Horsehead Industries Inc., was formed in 1987. It represents the merger of Horsehead's St. Joe operation (acquired from Fluor in 1987) and its New Jersey Zinc facilities (acquired in 1981).

Doe Run

Doe Run, the largest U.S. lead company, produces some byproduct zinc at its Buick mine. It accounted for 9 percent of U.S. zinc mine output in 1988.

Montana Tunnels

Montana Tunnels, a subsidiary of Pegasus Gold, opened its gold-silver-zinc-lead mine in 1987. The Jefferson, Montana operation accounted for 7 percent of U.S. zinc mine production in 1988.

Cominco

Cominco is a major Canadian minerals company that is among the world's largest lead and zinc producers. It is developing the Red Dog mine in Alaska, which is scheduled to begin production in 1990.⁹ This mine has estimated ore reserves of 77 million tonnes grading 17.1 percent zinc, 5 percent lead, and 80 grams/tonne silver. At its planned annual production of 325,000 tonnes of zinc in concentrates, Red Dog will be the world's largest zinc mine. It will nearly double U.S. zinc mine

⁹Cominco-Alaska is developing the mine and will operate it when it is commissioned. NANA (an Alaskan Native corporation) owns the mineral rights to the property.

production over 1989 levels. The mine will ship half of its concentrates to Cominco's Trail zinc-lead smelter in British Columbia and the rest to coastal smelters in the Far East and Europe.¹⁰

Cominco also owns half of the Magmont lead-zinc mine in Missouri. Magmont, which is currently the second largest lead mine in the country, accounted for 3 percent of U.S. zinc mine production in 1988. Dresser, a machinery manufacturer, is the other owner of Magmont.

Big River

Big River bought the Sauget, Illinois smelter/refinery from Amax Zinc in 1988. The plant accounts for about a quarter of domestic zinc processing capacity. The company has no mines.

Other Companies

The other major firms in the U.S. zinc industry are mining companies. Alta Gold recently opened a zinc mine in Nevada. Bunker Hill Mining, Star-Phoenix Mining, and New Butte Mining operate lead-zinc mines. Hecla, Greens Creek (a joint venture of RTZ, Hecla, Exalas Resources, and CSX Oil & Gas), and Washington Mining (in partnership with Alta Gold and Echo Bay) produce zinc from precious metals mines.

U.S. Interests in Other Countries

The U.S.-based companies that currently have foreign lead-zinc holdings are: Asarco, Phelps Dodge, and Cerro Copper. Asarco has ties to MIM, a large Australia-based producer of nonferrous metals and coal.¹¹ MIM has lead facilities in Australia (Mt. Isa mine) and the United Kingdom (the Britannia refinery) as well as equity interests in Cominco. Asarco also owns part of Medimsa which runs silver-lead-copper-zinc mines, mills, and smelters in Mexico. Phelps Dodge is primarily a copper company, but owns part of Black Mountain, a major lead-silver-zinc-copper mine in South Africa. Cerro Copper has interests in the Buenaventura zinc-lead mines in Peru. Two other U.S. firms have recently sold their foreign lead and zinc holdings. Amax sold its share of Fresnillo in Mexico. USX sold its share of the exhausted Prieska mine in South Africa.

Other Countries

Zinc and lead are often produced by the same set of countries and companies. To avoid repetition, the profiles of zinc and lead producers outside of the United States are given in chapter 4 only.

¹⁰State of Alaska, Division of Geological and Geophysical Surveys, *Alaska's Mineral Industry, Special Report 43, 1988.*

¹¹Asarco owns 19 percent of MIM, and MIM owns 25 percent of Asarco. The relationship is one of passive ownership and entails little operational control.