

## INTRODUCTION

Lead, one of the oldest known metals, has been used since 3000 BC. In the 20th century, the development of froth flotation techniques reduced production costs dramatically and made previously uneconomic deposits viable. The use of lead increased greatly with invention of the electric starting system (which required storage batteries) for automobiles.

### Uses

Batteries are lead's largest market. In the United States, lead acid storage batteries accounted for 78 percent of domestic lead consumption in 1988. These batteries are used for auto ignition starters, uninterruptible power supplies (for computer systems at hospitals, banks, and communications networks), and standby power supplies (for emergency lighting and telephone systems). Other major uses include paints, glasses, and ceramics additives (5 percent of domestic consumption), ammunition (4 percent), solder (2 percent), building products, pipes, traps, and cable coverings.<sup>1</sup> Lead's use as a gasoline additive declined greatly in the last two decades because of environmental regulations.<sup>2</sup> This, and other, decreases in lead's dissipative uses has made the metal more recyclable and increased the importance of the secondary market.

### Production Methods and Technologies

Lead is produced from galena (PbS), and less commonly, cerussite (PbCO<sub>3</sub>) and anglesite (PbSO<sub>4</sub>). Commercial ores contain 4 to 12 percent lead. Galena often contains silver/gold and is associated with sphalerite (ZnS), pyrite (FeS<sub>2</sub>), and

chalcopyrite (CuFeS<sub>2</sub>). Thus, byproduct and coproduct recovery are frequently important aspects of lead production.

Over 80 percent of nonsocialist world (NSW) lead mines are underground operations. After mining, the ores are beneficiated (at the minesite) to raise the lead content and to remove most of the associated zinc, iron, and waste rock. Any copper, silver, and gold, in the ore normally remain with the lead and are recovered at the smelter or refinery. A variety of separation processes are used to concentrate lead ores, but froth flotation is generally used for sulfide ores such as galena. The resulting concentrate contains about 70 percent lead.

At the smelter, the lead concentrates are pelletized and sintered to remove most of the sulfur. The lead oxide sinter product is then charged (along with coke, fluxes, and dross) into the top of the blast furnace or the Imperial smelting furnace.<sup>4</sup> As the feed descends through the furnace, the burning coke melts the charge and forms a gas which reduces the lead oxide to metallic lead. The lead, called bullion, and the slag are tapped from the bottom of the furnace. The process is continuous. The slag carries out most of the zinc, iron, silica, lime, and other gangue. The bullion, which contains silver, gold, and copper, is transferred to dressing kettles. As the bullion cools, most of the copper becomes insoluble and separates out into the dross which is skimmed off.<sup>5</sup> The decopperized bullion is then sent to the refinery.

Most lead bullion is refried by pyrometallurgical methods.<sup>6</sup> This involves a series of processes that remove the antimony (softening), silver (Parkes process), zinc (vacuum dezincing), and, if need be,

<sup>1</sup>William D. Woodbury, "Lead," *Minerals Yearbook*, vol. I, 1988 ed. (Washington DC: U.S. Department of the Interior, Bureau of Mines, 1990).

<sup>2</sup>Gasoline additives nevertheless still account for a significant portion of world lead use, principally in less developed countries (LDCs).

<sup>3</sup>A.L. Ponikvar, "Lead Metallurgy," *McGraw-Hill Encyclopedia on Science and Technology* (New York, NY: McGraw-Hill, 1987). William D. Woodbury, "Lead," *Mineral Facts and Problems*, 1985 ed. (Washington, DC: U.S. Department of the Interior, Bureau of Mines, 1985).

<sup>4</sup>The Imperial Smelting Process (ISP), developed in the 1950s, is used mostly in Europe, Japan, and Australia. It is basically a conventional blast furnace with a zinc recovery section added. It can produce both lead and zinc from a variety of mixed, low-grade, and oxide concentrates. Two relatively new lead smelting technologies have found limited use. They are the Queneau-Schumann-Lurgi (QSL) process developed in West Germany and the Kivcet process developed in the Soviet Union. Both combine the sintering (oxidation) and blast furnace (reduction) functions into one autogenous, direct reduction unit.

<sup>5</sup>A second dressing is performed if tin removal is necessary.

<sup>6</sup>An alternative method, electrolytic processing, is used to refine bullion with high bismuth levels. In this process, softened bullion is cast into anodes and placed in an electrolytic cell. The lead is refried when the electric current removes it from the anode and redeposits it on the cathode starter sheet.

bismuth (Betterton-Kroll process). The first step, softening, removes the antimony, arsenic, and tin by air oxidation in a reverberatory furnace or by the Harris process. Next, in the Parkes process, zinc is added to the melt to remove the silver and gold. The zinc, silver, and gold form insoluble compounds which are skimmed off the melt. The remaining traces of zinc are then removed by vacuum dezincing or by chlorine treatment. When necessary, bismuth is removed from the lead by the Betterton-Kroll process. The melt is treated with calcium and magnesium which alloy with the bismuth to form a crust which is skimmed off. In the United States most lead ore is smelted and refined to a minimum purity of 99.85 percent lead. Throughout the smelting and refining stages, the many dresses, slags, and slimes are worked up to recover their values of precious and base metals.

## THE 1980s

The U.S. lead market started the 1980s on a mixed note (see figures 4-1 and 4-2). In 1980, lead prices (averaging \$0.43/lb) were high compared with the late 1970s. Primary and secondary lead production (550,000 and 600,000 tonnes respectively) though were roughly equivalent to late- 1970s levels.

Prices fluctuated downward to an average of \$0.24/lb in 1982-84 and \$0.21/lb in 1985-86, but then recovered to an average of \$0.38/lb in 1987-89. Fluctuations in lead production levels from 1980 to 1989, left U.S. mine production down 21 percent, primary refined production down 28 percent, and secondary production up 23 percent.

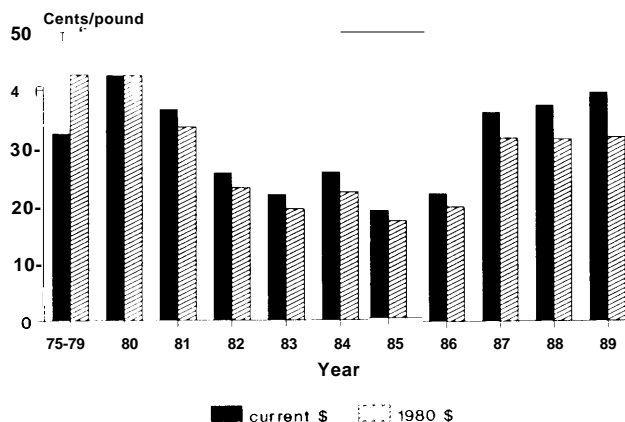
Secondary lead increased its importance in the U.S. market during the 1980s. The ratio of primary to secondary production shifted from roughly 50:50 in 1980 to 35:65 in 1989.<sup>7</sup> U.S. lead consumption held fairly steady at 1.1 million tonnes during 1980-87. It then increased slightly to 1.2 million tonnes in 1987-89.

For the nonsocialist world as a whole, the lead market fluctuations were more muted (see figure 4-3). The 1988 levels for NSW mine production and primary refined production were equal or slightly

<sup>7</sup>These figures represent the refined lead recovered from both new and old scrap. As such they overstate the amount of refined lead that is actually entering the manufacturing stream. Old scrap comes from discarded products, new scrap is waste from fabricating and other manufacturing processes. In 1988, 737,000 tonnes of secondary lead were recovered from old scrap (691,000 tonnes) and new scrap (46,000 tonnes), and recovered as refined metal (698,000 tonnes) and other "non-refined" products (39,000 tonnes). William D. Woodbury, "Lead," *Minerals Yearbook*, vol. I, 1988 ed. (Washington, DC: U.S. Department of the Interior, Bureau of Mines, 1990).

<sup>8</sup>By Convention the elements in multimineral ores mines are listed in order of their descending value (based on price and abundance) in the ores.

Figure 4-1—Lead Prices, 1975-89



NOTE: North American primary producers list price-refined lead delivered. Prices in constant 1980 dollars were calculated using producer price index. Bars labeled 75-79 represent averages for the period 1975-79.

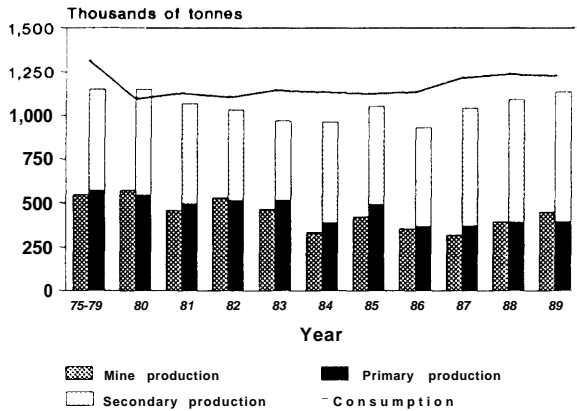
SOURCE: U.S. Bureau of Mines.

lower than those of 1980. Secondary lead production rose 18 percent, and consumption rose 12 percent, during 1980-88.

The openings, closings, and ownership changes that occurred in the U.S. primary lead industry during the 1980s are profiled in table 4-1. Two new lead mines (West Fork and Casteel) and two lead-producing precious metals mines (Greens Creek and Montana Tunnels) opened during the decade. 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.<sup>8</sup> These six new mines are in Missouri, Alaska, and Montana. Two mines that produced lead were permanently closed. Many more mines closed temporarily at some time during the 1980s, because of low prices. In the processing sector, two smelters and one refinery were closed permanently, and no new ones opened. During 1980-88, U.S. smelter capacity declined 28 percent to 515,000 tonnes and refinery capacity declined 17 percent to 595,000 tonnes.

Doe Run, the country's dominant lead producer, was created in 1986 through the merger of the lead assets of Fluor and Homestake. Fluor had acquired

**Figure 4-2—U.S. Lead 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.

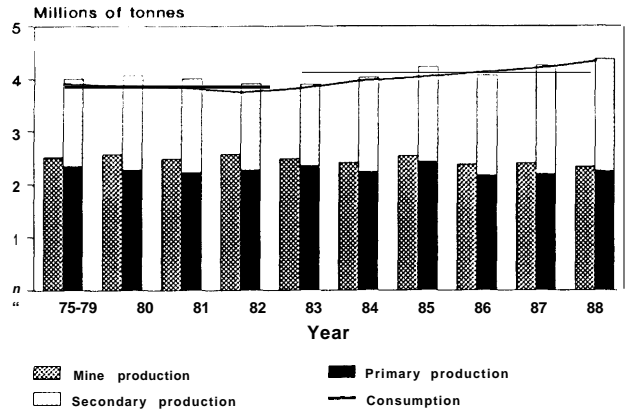
its contribution to the venture through the purchase of St. Joe in 1981. Homestake had acquired full control of its lead facilities (the Buick mine and Boss smelter/refinery) earlier in 1986. During 1986-90, Doe Run was owned 57.5 percent by Fluor and 42.5 percent by Homestake. Fluor bought out Homestake in May 1990 and is now the sole owner of Doe Run.

Asarco built one mine and bought another during the decade. Previously, Asarco's involvement in the lead industry had been mostly in the processing sector. Other new lead mining companies include Montana Tunnels, Greens Creek, Washington Mining, Bunker Hill Mining, Star-Phoenix Mining, New Butte Mining, and Cominco-NANA. Four companies (Ozark Lead, Bunker Hill, Amax, and Standard Metals) left the U.S. industry during the 1980s. Ozark Lead was a subsidiary of Kennecott.

## PRODUCER PROFILES, 1990

Lead and zinc tend to occur in the same ores, so they are often mined, and sometimes processed, jointly. The same set of countries and companies, therefore, dominate the production of both metals (see figures 4-4 and 5-4). To avoid repetition, the lead and zinc profiles of most countries are presented together in this chapter. The two industries in the United States, being more separate than those

**Figure 4-3--NSW Lead 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.

elsewhere, and are discussed in the respective lead and zinc chapters.

Most lead is produced in industrialized countries. Compared with copper, very little lead capacity is government-owned. Developed countries account for about 70 percent of mine capacity and even greater percentages of primary smelter/refinery capacity.<sup>9</sup> Australia, the United States, Canada, and Mexico are large producers in both the mining and processing sectors. Peru is a large mine producer, but has little processing capacity. Japan and Europe have large smelting/refining *sectors*. Secondary (recycled) lead accounts for major proportions of production in North America, Japan, and Western Europe.

### United States

The United States is a major producer of lead, ranking second in mining and first in both primary and secondary refining. Recycled lead accounts for about two-thirds of total domestic refined production. U.S. trade in concentrates is relatively small. Concentrate imports have declined about 70 percent since the 1960s, when the United States had a large custom smelting/refining industry. Processing is now closely tied to the level of regional mine production. For refined lead, the United States imports about 12 percent of its needs. During

<sup>9</sup>In this report, little distinction is made between the smelting and refining sectors of the lead industry. Smelting and refining are often, though not always, carried out at the same facilities.

Table 4-I—Profile of U.S. Primary Lead Production Industry, 1980 and 1990

	1980	1990	
<b>Major mines:</b>			
<b>Lead mines:</b>			
West Fork, MO	—	Asarco	Opened 1985
Sweetwater (Milliken), MO	Ozark Lead <sup>a</sup>	Asarco	Closed 1983; sold to Asarco 1986; reopened 1987
Magmont, MO	Cominco-Dresser <sup>b</sup>	Cominco-Dresser <sup>b</sup>	
Buick, MO	Amax-Homestake <sup>c</sup>	Doe Run <sup>d</sup>	Amax share sold to Homestake 1986; Note 1
Fletcher, MO	St. Joe	Doe Run <sup>d</sup>	Notes 2&1
Viburnum #29, MO	St. Joe	Doe Run <sup>d</sup>	Notes 2&1
Casteel (Viburnum #35), MO	—	Doe Run <sup>d</sup>	Opened 1984; owned by Fluor (St. Joe); Note 1
Viburnum #28, MO	St. Joe	Doe Run <sup>d</sup>	Notes 2&1
Brushy Creek, MO	St. Joe	—	Closed 1984; Notes 2&1
Indian Creek, MO	St. Joe	—	Closed 1982; Notes 2&1
<b>Mixed lead-zinc mines:</b>			
Leadville, CO	Asarco-Newmon <sup>e</sup>	Asarco-Newmon <sup>e</sup>	
Bunker Hill, ID	Bunker Hill <sup>f</sup>	Bunker Hill Mining	Closed 1981; Note 3; reopened 1988
Red Dog, AK	—	Cominco-NANA <sup>g</sup>	Opened 1990
Butte Hill, MT	—	New Butte Mining	Closed since early -1970s; reopened 1990
Star-Morning Unit, ID	Bunker Hill-Hecla <sup>h</sup>	Star-Phoenix Mining	Closed 1982; Star-Phoenix signed 10 year lease-purchase agreement 1989; reopened 1990
<b>Precious metals mines:</b>			
Greens Creek, AK	—	Greens Creek <sup>k</sup>	Opened 1989; Note 4
Lucky Friday, ID	Hecla	Hecla	
Montana Tunnels, MT	—	Montana Tunnels <sup>l</sup>	Opened 1987; Note 5
Sunnyside, CO	Standard Metals	Washington Mining <sup>m</sup>	Sold to Echo Bay 1985; Note 6
<b>Smelters:</b>			
Glover, MO	Asarco	Asarco	
East Helena, MT	Asarco	Asarco	
El Paso, TX	Asarco	—	Closed 1985
Kellogg, ID	Bunker Hill <sup>f</sup>	—	Closed 1981 (indefinite), 1985 (permanent)
Herculaneum, MO	St. Joe	Doe Run <sup>d</sup>	Notes 2&1
Boss, MO	Amax-Homestake <sup>c</sup>	Doe Run <sup>d</sup>	Amax share sold to Homestake 1986; Notes 1&7
<b>Refineries:</b>			
Glover, MO	Asarco	Asarco	
Omaha, NB	Asarco	Asarco	
Kellogg, ID	Bunker Hill <sup>f</sup>	—	Closed 1981
Herculaneum, MO	St. Joe	Doe Run <sup>d</sup>	Notes 2&1
Boss, MO	Amax-Homestake <sup>c</sup>	Doe Run <sup>d</sup>	Amax share sold to Homestake 1986; Note 1&7

**NOTES:**

<sup>a</sup>Ozark Lead was a subsidiary of Kennecott, a subsidiary of Standard Oil (SOHIO), a majority-owned subsidiary of British Petroleum.

<sup>b</sup>Cominco and Dresser Industries each own 50% of the Magmont mine.

<sup>c</sup>Cominco is the operator.

<sup>d</sup>Amax and Homestake each owned 50 percent of the Buick mine and the Boss smelter/refinery.

<sup>e</sup>Doe Run is a subsidiary of Fluor.

<sup>f</sup>Asarco and Newmont each own 50 percent of the Leadville mine. Asarco is the operator.

<sup>g</sup>Bunker Hill was a subsidiary of Gulf Resources and Chemical Corp.

<sup>h</sup>Cominco-Alaska developed and operates the Red Dog mine. NANA owns the mineral rights.

<sup>i</sup>Th Star Morning Unit was owned 70% by Bunker Hill and 30% by Hecla. It was operated by Hecla.

<sup>j</sup>Greens Creek mine is a joint venture of RTZ, Hecla, Exalax Resources Corp. (a subsidiary of Mitsubishi), and CSX Oil & Gas Corp.

<sup>k</sup>Montana Tunnels is a subsidiary of Pegasus Gold.

<sup>l</sup>Sunnyside 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.

<sup>1</sup>Lead 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.

<sup>2</sup>St. Joe acquired by Fluor 1981.

<sup>3</sup>Bunker Hill, ID mine was sold to Bunker Hill Ltd. partnership 1982. Bunker Hill Mining created in public spinoff 1988.

<sup>4</sup>Exploration and development led by Noranda 1981-86, British petroleum 1986-1989; Hecla became a minority partner 1987; RTZ became majority holder 1989.

<sup>5</sup>Owned 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 Gold 1987.

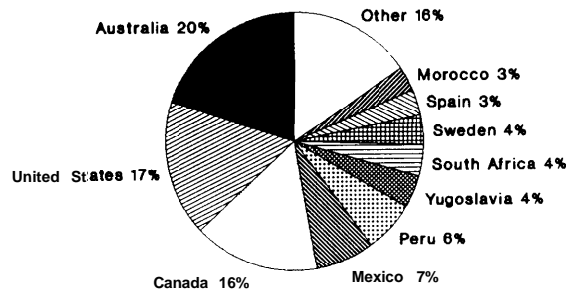
<sup>6</sup>Echo Bay and Alta Gold (owned by Silver King and Pacific Silver) formed the Alta Bay Venture in June 1988. Alta Bay is 60% owned by Alta Gold and 40% owned by Echo Bay. Echo Bay contributed the Sunnyside, CO mine and other properties to the venture. Washington Mining (which owns the property) became a 35% partner in November 1988 and the mine operator in January 1989. Alta Bay owns the remaining 65%.

<sup>7</sup>Boss, MO facility operating at about one-quarter of its capacity 1990. Secondary lead recovery unit to be added in late-1990.

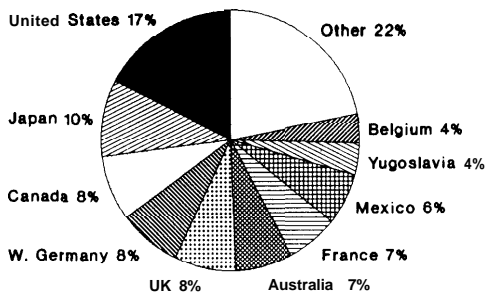
SOURCE: Office of Technology Assessment, 1990. Compiled from *Minerals Yearbook* (various issues), U.S. Bureau of Mines (Washington, DC).

Figure 4-4--NSW Lead Production, Country Profile, 1988

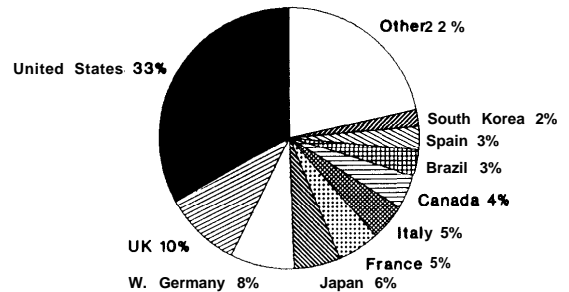
Mine Production  
2.3 million tonnes



Primary Production  
2.3 million tonnes



Secondary Production  
2.1 million tonnes



NOTE: Secondary production is refined metal recovered from old and new scrap.  
SOURCE: *Metal Statistics 1978-1988*, Metallgesellschaft Aktiengesellschaft.

1985-88, the largest suppliers were Canada (63 percent of imports) and Mexico (22 percent).<sup>10</sup>

All U.S. lead mines are located in southeastern Missouri's Viburnum Trend, which was discovered and developed in the late- 1960s. These facilities are considered low-cost and competitive in the world market. Their ores are easy to process, because they are relatively homogeneous (containing few byproducts) and mineralogically simple. Furthermore, the deposits are large and amenable to highly mecha-

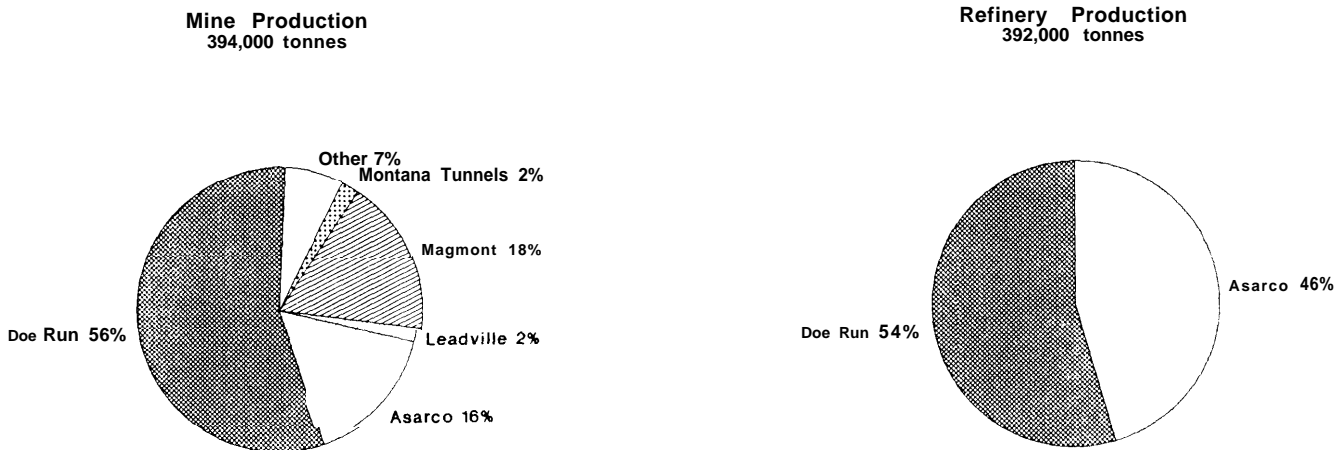
nized excavation.<sup>11</sup> Lead is also produced as a byproduct or co-product at mines in Alaska, Colorado, Idaho, and Montana. Domestic processing facilities are located in Missouri, Montana, and Nebraska.

Two firms, Doe Run and Asarco, dominate the domestic lead industry (see figure 4-5). Together they account for three-quarters of domestic mine production and all primary refined production.

<sup>10</sup>U.S. Department of the Interior, Bureau of Mines, *Mineral Commodity Summaries*, 1990 ed. (Washington, DC:1990).

<sup>11</sup>U.S. Congress, Congressional Research Service, *The Competitiveness of American Mining and Processing*, report prepared for the House Committee on Energy and Commerce, Subcommittee on Oversight and Investigations, Committee Print 99-FF (Washington, DC: U.S. Government Printing Office, July 1986).

Figure 4-5--U.S. Lead Industry, Company Profile, 1988



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

### Doe Run

Doe Run is the largest U.S. lead producer. It accounted for 56 percent of domestic mine production and 54 percent of primary refinery capacity in 1988. It operates six mines, four mills, and two smelter/refineries in the Viburnum lead belt.<sup>12</sup> Doe Run's Buick mine is the largest lead mine in the country. The company was established in 1986 when Fluor combined its St. Joe operations with those of Homestake.<sup>13</sup> In May 1990, Fluor bought out Homestake's 42.5 percent share in Doe Run. Fluor has reportedly been trying to sell its share in Doe Run and sole ownership is expected to make the sale easier.<sup>14</sup> Lead accounts for nearly all of Doe Run's sales, but only a small part of those of Fluor.<sup>15</sup> Fluor is primarily an engineering, construction, and technical services company. It also has coal interests.

### Asarco

Asarco's domestic lead operations include two lead mines in Missouri, two smelters (East Helena, Montana and Glover, Missouri), and two refineries

(Omaha, Nebraska and Glover, Missouri). The company also operates the Leadville, Colorado zinc-lead-gold-silver mine which it owns jointly with Newmont. These facilities accounted for 18 percent of domestic mine production and 46 percent of refining capacity in 1988.<sup>16</sup>

Asarco is a multinational diversified minerals producer whose primary businesses are copper, silver, gold, lead, zinc, and other nonferrous metals. Lead accounted for 6 percent of the company's sales in 1988.<sup>17</sup> Originally a smelting and refining company, Asarco has been trying for several years to build up its own sources of concentrates. In 1988, 60 percent of the lead concentrates required by the company smelters were supplied by its own mines. This compares with 3 percent in 1985.<sup>18</sup>

### 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

<sup>12</sup>The BOSS smelter is currently being outfitted to process scrap lead.

<sup>13</sup>The St. Joe operations included five mines, three mills, and the Herculanum smelter/refinery. Homestake contributed the Buick mine and mill and the Boss smelter/refinery.

<sup>14</sup>James H. Jolly, "Mineral Industry Surveys," *Zinc Industry Monthly* (Washington, DC: U.S. Department of the Interior, Bureau of Mines, March 1990).

<sup>15</sup>In 1988, Doe Run accounted for 2.4 percent of Fluor's revenues. Fluor Annual Report, 1988.

<sup>16</sup>This figure includes the entire production of the Leadville mine.

<sup>17</sup>Not including Asarco's nonconsolidated subsidiaries (MIM, Medimsa, and SPCC).

<sup>18</sup>Asarco Annual Report, 1988.

Alaska, which is scheduled to begin production in 1990.<sup>19</sup> 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 70,000 tonnes of lead in concentrates, Red Dog will be the country's third or fourth largest lead mine. It will increase U.S. lead mine production by 16 percent 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.<sup>20</sup>

Cominco also owns half of the Magmont lead-zinc mine in Missouri. Magmont, which accounted for 18 percent of U.S. mine production in 1988, is currently the second largest lead mine in the country. Dresser, a machinery manufacturer, is the other owner of Magmont.

#### Other Companies

The other major firms in the U.S. lead industry are mining companies. Bunker Hill Mining, Star-Phoenix Mining, and New Butte Mining operate lead-zinc mines. Hecla, Montana Tunnels (a subsidiary of Pegasus Gold), Greens Creek (a joint venture of RTZ, Hecla, Exalco Resources, and CSX Oil & Gas), and Washington Mining (in partnership with Alta Gold and Echo Bay) produce lead 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,<sup>21</sup> 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 34 percent of Medimsa which runs silver-lead-copper-zinc mines, mills, and smelters in Mexico. Phelps Dodge is primarily a copper company, but owns 45 percent of Black Mountain, a major lead-silver-zinc-copper mine in South Africa. Cerro Copper owns 34 percent of 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.

#### Canada

Canada is the largest NSW zinc producing country and third ranking lead producer.<sup>22</sup> It is also a major exporter of lead and zinc. During 1985-88, about 40 percent of its concentrate output was exported, primarily to Japan, Belgium, and West Germany. Of its refined metal output, Canada exports about half of its lead and three-quarters of its zinc. The United States is the major destination for both refined products.

Production in Canada is dominated by Cominco, Noranda, and their subsidiaries. These two companies are especially strong in the processing sector. They control all of Canada's lead processing capacity and about 70 percent of its zinc processing capacity. In the lead mining sector, they, along with the Faro joint venture, are the major producers. The zinc mining industry is somewhat more broad based, with Falconbridge, Hudson Bay, Nanisivik, and Westmin having some presence.

Cominco (partially owned by Teck, MIM, and MG) is a major nonferrous metals producer. It has major zinc-lead mines in western (Sullivan, British Columbia) and northern (Polaris, Northwest Territories) Canada, and interests in mines in the United States (Magmont and Red Dog), Australia (Aberfoyle), and Spain (Exminesa). The company is especially adept at Arctic mining.

Cominco has a major lead smelter and zinc electrolytic refinery at Trail, BC and an interest in the Mitsubishi-Cominco lead smelter/refinery in Japan. The Trail plant processes the concentrates from Sullivan and other Canadian mines. The company sells, buys, and toll refines large amounts of concentrates.

Cominco claims to account for about 10 percent of NSW mine production of lead and zinc.<sup>23</sup>

<sup>19</sup>Cominco-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.

<sup>20</sup>State of Alaska, Division of Geological and Geophysical Surveys, *Alaska's Mineral Industry*, Special Report 43, 1988.

<sup>21</sup>Asarco owns 19 percent of MIM, and MIM owns 25 percent of Asarco. The relationship is one of passive ownership and entails little operational control.

<sup>22</sup>Canada produces nearly all of its lead and about half of its zinc from mixed ores.

<sup>23</sup>Cominco Annual Report, 1988.

Three-quarters of the company's sales are from the metals business, including copper, lead, zinc, silver, gold, molybdenum, cadmium, bismuth, iridium, and fabricated metals. The company also has a substantial fertilizer business.

Noranda, active primarily in eastern Canada, is focused more on zinc than lead. Its Brunswick operations produce zinc-lead ore and its Ontario/Quebec mines produce zinc-copper ore. Noranda is a diversified natural resources company with interests in nonferrous minerals and forest, energy, and manufactured products. The nonferrous segment produces zinc and lead, but also large quantities of gold, silver, and copper.<sup>24</sup> Noranda's lead business is run through its partial ownership of Brunswick which has a mine and a smelter in New Brunswick. The zinc business is comprised of mines in Ontario and Quebec (run by Brunswick and Noranda itself) and a zinc refinery at Valleyfield, Quebec (run by the Canadian Electrolytic Zinc subsidiary).

The Faro joint venture operates a large zinc-lead-silver mine in the Yukon. The mine reopened 1986 and is currently owned by Curragh Resources and Boliden. Faro's concentrates are sent to the Far East and Europe for processing.

Falconbridge, best known as the world's second largest nickel producer, mines copper-zinc ores at its Kidd Creek facilities in Timmins, Ontario. About half of the concentrates are processed onsite and the other half are shipped elsewhere. In late 1989, Falconbridge was bought by Noranda and Trelleborg of Sweden.<sup>25</sup>

Other Canadian zinc facilities are Hudson Bay's Flin Flon mine and smelter in Manitoba; Westmin's Myra Falls mine in British Columbia; and the Nanisivik mine in the Northwest Territories. Hudson Bay is owned by Inspiration Resources, which in turn is controlled by Anglo American of South Africa. Westmin and Noranda are both partially owned by Brascan.

### *Australia*

Australia is a major lead and zinc producer whose industries have grown significantly in the last 10 to 15 years. It exports about 90 percent of its lead and

zinc output. During 1985-88, Australia exported 23 percent of its lead as concentrates (mostly to Japan and Belgium), 44 percent as bullion (to the United Kingdom), and 34 percent as refined lead. About 70 percent of the zinc exports during this period were in the form of concentrates (mostly to Japan, Europe, and South Korea), with the remainder being shipped as slab zinc. There has been a great amount of exploration and development in Australia in recent years, much of it has focused on zinc.

Australia's major lead and zinc companies are Pasminco and MIM. Pasminco was created by the merger of the lead and zinc operations of CRA (partially owned by RTZ) and New Broken Hill Holdings (NBHH) in July 1988. CRA and NBHH each own 40 percent of the company, the remainder is publicly held. Pasminco accounts for an estimated 45 percent of Australia's lead mine production and about half of its zinc mine production. It also operates all of the country's lead and zinc processing capacity, except for one lead bullion smelter (MIM). In terms of refined metal, Pasminco accounts for an estimated 10 percent of NSW zinc production and 7 percent of lead output.<sup>26</sup>

Pasminco's lead-zinc mines are centered in the Broken Hill area of New South Wales. The mines have rich ores, but are considered high cost operations. The company processes concentrates from all over Australia at its Port Pirie (South Australia), Risdon (Tasmania), and Cockle Creek (New South Wales) smelters. It also operates the country's only lead refining facility (Port Pirie). Pasminco's interests outside of Australia include the AM&S lead-zinc smelter at Avonmouth in the United Kingdom and partial ownership of the Budelco zinc smelter in the Netherlands.

MINI owns the silver-zinc-lead complex at Mt. Isa/Hilton (Queensland) which accounts for about 35 and 30 percent of Australia's production of lead and zinc respectively. Some of the lead is shipped out as concentrates. Most, however, is smelted into bullion onsite and then shipped to the company's Britannia refinery in the United Kingdom or to Japan. All of the zinc is sold as concentrates. MIM's lead and zinc interests outside of Australia include the Britannia lead refinery, partial ownership of

<sup>24</sup>Noranda's aluminum smelting facilities are included in its manufacturing sector.

<sup>25</sup>Trelleborg also owns 50 percent of Boliden, a Sweden-based nonferrous metals producer.

<sup>26</sup>Ian Hammond, "CRA—The Australian Connection," *Engineering and Mining Journal*, vol. 190, No. 8, August 1989.



Ruhr Zink (a West German zinc refining firm) and ties to Asarco, Cominco, Teck, and Metallgesellschaft.

Australia's other producers operate zinc-lead mines. Aberfoyle (partially owned by Cominco) has mines at Hellyer and Que River in Tasmania. A project that quadrupled Hellyer's capacity was completed in March 1989. Nicron runs the Woodcutters mine in the Northern Territory. The Cadjebut mine (owned by BHP and Billiton) in West Kimberly, West Australia began production in 1987. The Lady Loretta and Thalanga mines (owned by Pancontinental and Outokumpu) in Queensland are expected to be brought on-stream in 1990.

### *Mexico*

Mexico is a medium-sized lead and zinc producer. Most of its output comes from mines where silver is the primary interest. The country exports about 60 percent of its lead and about two-thirds of its zinc. The lead is shipped mostly as refined metal. The zinc is exported as both concentrates and slab zinc.

Mexican mine production is dominated by Medimsa, Penoles, Real des Angeles, and Frisco. These four companies account for about 80 percent of the country's lead mine output and 90 percent of its zinc mine output.<sup>27</sup> Penoles and Medimsa operate nearly all of Mexico's lead and zinc processing capacity.

Medimsa (owned by IMM and Asarco) is the largest lead and zinc producer in Mexico. It operates seven silver-zinc-lead mines, a lead smelter at Avalos Chihuahua and smelter/refinery at Monterrey, and a zinc refinery at San Luis Potosi. Medimsa processes all of its output of lead concentrates, but sells or has tolled about half of its zinc concentrates.

Penoles operates a number of smaller mines (either directly or through its partially owned Fresnillo subsidiary) and a large smelter/refinery at Torreon, Coahuila. The processing facility produces more lead and zinc than do the company's mines. Of the refined metal produced, roughly 60 percent of the lead and 35 percent of the zinc is based on purchased or tolled concentrates.

Frisco operates two smaller silver-zinc-lead mines and has an interest in the Real des Angeles

lead-zinc mine. The Real des Angeles silver-lead concentrates are processed at the Penoles smelter.

### *Peru*

Peru has a medium-sized mining industry and a small processing sector. Most of the lead and zinc comes from multimetallic ores that are mined principally for their silver. Peru exports about two-thirds of its lead and zinc concentrates.

Centromin (owned by the Peruvian government) accounts for about 30 percent of the country's lead mine production and about 40 percent of its zinc mine production. The company has five silver-zinc-lead mines. It also has a processing plant (La Oroya) that encompasses a lead smelter/refinery and an electrolytic zinc refinery. All of Centromin's lead concentrates and a quarter of its zinc concentrates are processed at La Oroya.

The remainder of Peru's lead and zinc mine production is from smaller local independent producers such as San Ignacio Morococha (the largest private zinc mine), Milpo (the largest private lead mine), and Atacocha. There are also some smaller mining companies held by foreign interests, including Nor Peru (partially owned by Asarco), Huaron (partially owned by Metaleurop), Santander (owned by Docarb), and Buenaventura (partially owned by Cerro Copper, Centromin, and the World Bank). Peru also has two additional processing facilities. Mineroperu (owned by the government) runs a zinc refinery at Cajamarquilla. Fundeconsa operates a small lead refinery at Sayan.

Mineral production in Peru has been plagued by political strife, labor strikes, and natural disasters. These perennial problems deter foreign investment in Peru's industry. Little growth is expected in Peruvian production for some time.

### *Japan*

Japan has some mine production, but is primarily a processing country. It is the NSW's second largest producer of both refined lead and refined zinc. Japan imports about three-quarters of its zinc concentrates and 90 percent of its lead concentrates. Australia, Canada, and Peru are the largest suppliers. Japan is roughly self-sufficient for refined lead and a net

<sup>27</sup>Orlando Martino, "The Mineral Industry of Mexico," *Minerals Yearbook*, vol. III, 1986 ed. (Washington, DC: U.S. Department of the Interior, Bureau of Mines, 1988).

importer of refined zinc. The principal zinc suppliers are North and South Korea.

Four companies (Dowa, Mitsui, Nippon Mining, and Mitsubishi) have both mines and processing facilities in Japan. Four others (Akita Zinc, Toho Zinc, Hachinoe, and Sumitomo) have only smelter/refineries. The principal owners of Akita Zinc and Hachinoe are Dowa and Mitsui, respectively. All of these companies, except for Dowa in the lead sector, must purchase or toll concentrates to maintain their economic processing levels. Mitsubishi and Cominco are involved in a joint venture to process the latter's Canadian lead concentrates.

### *Spain*

Spain is Europe's largest zinc miner and second largest lead miner. The mines, located in the southwestern part of the country, contain complex ores that are relatively difficult to process. The major lead and zinc mining companies are Exminesa, Boliden, Asturiana de Zinc, and Almagrera. Spain's smelting/refining companies are Metaleurop, Asturiana de Zinc, and Espanola de Zinc. Metaleurop, which owns the largest lead smelter, produces over three-quarters of the country's refined lead. Asturiana de Zinc, the largest zinc smelter, accounts for roughly 80 percent of Spain's refined zinc output.

### *Sweden*

Sweden exports about one-quarter of its lead concentrates and all of its zinc concentrates (primarily to Finland, Norway, and France). The industry is dominated by Boliden, which accounts for roughly 60 percent of the country's lead and zinc mine production and all of its refined lead production. The company smelts its lead concentrates at Ronskar and ships the zinc concentrates to its partially owned Norzink subsidiary in Norway. Boliden's other foreign holdings include the Black Angel mine in Greenland and a small interest in the Faro mine in Canada.

Most of the rest of Sweden's mine output is produced by Vieille Montagne (part of Acec-Union Miniere). This company's lead concentrates are sent to Boliden's Ronskar plant; the zinc concentrates are sent to its own facilities in France.

### *Ireland*

Ireland is a small zinc mine producer. It has one mine and no smelting/refining capacity. Tara

(owned by Outokumpu and the Irish government) runs the Navan zinc-lead-silver mine. It is Europe's largest zinc mine. The concentrates are all sent to other European countries for processing.

### *Yugoslavia*

Yugoslavia has five lead-zinc producers, all of which are government-owned. RMHK Trepca is the largest. The ores are multimetallic and have a higher proportion of lead than is found in most places except the United States. Almost all of the concentrates are processed domestically.

### *West Germany*

Germany is Europe's largest primary lead and zinc smelter/refiner. It is also a major secondary lead producer. It imports over 80 percent of its lead concentrates and bullion. Metallgesellschaft (MG) and Metaleurop dominate production in Germany. MG runs the country's only lead and zinc mines, and operates several smelters, through its Berzelius Metallhütten subsidiary. It also has interests in the Norddeutsche Affinerie (owned by MG, MIM, and Degussa) lead plant, and the Ruhr Zink (owned by MG and MIM) zinc plant. Metaleurop was created in 1988 by the merger of Preussag (Germany) and Penarroja (France). It is now Europe's largest lead producer and second largest zinc producer (after Vieille Montagne). In Germany, Metaleurop has lead and zinc processing facilities at Nordenham. The company has additional plants in Spain and France.

### *France*

France has three lead and zinc processing facilities, for which it imports most of the required concentrates. The largest concentrate suppliers are Canada, Sweden, Peru (zinc), and South Africa (lead). Metaleurop accounts for all of France's refined lead production and about one-third of its zinc production. The company has a large complex at Noyelles-Godault, Pas de Calais. The facility is somewhat rare in that it produces nearly twice as much lead as zinc. The other two-thirds of the country's refined zinc production comes from Vieille Montagne's plants at Aubry.

### *United Kingdom*

*The* United Kingdom has one primary lead refinery, the Northfleet plant run by MIM's Britannia subsidiary. This facility refines lead bullion from

the MIM Mt. Isa complex in Australia. Pasminco has a lead and zinc smelter at Avonmouth. Its lead bullion is exported to refineries in Italy, Germany, and Belgium.

### ***Belgium***

Belgium imports all of the concentrates needed by its lead and zinc processing industry. The largest suppliers are Peru, Australia, and Greece for lead concentrates, and Canada, France, and Mexico for zinc concentrates. Belgium's capacity is essentially all controlled by Acec-Union Miniere through two of its subsidiaries, MHO and Vieille Montagne. MHO runs all the country's lead capacity and roughly 45 percent of its zinc capacity. The company's lead (and copper) facilities are at Hoboken and its zinc operations are at Overpelt. Vieille Montagne's Balen plant accounts for the rest of Belgium's zinc production.

### ***The Netherlands***

The Netherlands' only primary zinc plant is Europe's largest. It is run by Budelco (owned by Billiton and Pasminco) and processes concentrates from Canada, Australia, and Ireland.

### ***Italy***

Italy is a medium-sized zinc producer. Its industry is dominated by Metaleurop's Pertusola subsidiary and Nuova Samim (partially government-owned). Pertusola accounts for about 55 percent of the country's zinc production. Nuova Samim accounts for the remainder of the zinc and a small amount of lead production. The zinc concentrates come from Canada, Ireland, and Peru.

### ***Finland***

Finland has one producer, Outokumpu. It mines mostly zinc, but also a little lead. The concentrates, along with those from the Tara subsidiary in Ireland,

are processed at the company's Kokkola smelter/refinery.

### ***Norway***

Norway's only producer, Norzink (owned by Boliden and RTZ), refines zinc at Eitrheim. The principal sources of its feed materials are Boliden's Swedish mines and smelters.<sup>28</sup>

### ***Other Countries***

Other large producers around the world include: Black Mountain and ZC South Africa in South Africa; Touissit, Djebel Aouam, and Zellidja in Morocco; CMM and Paraibuna in Brazil; Korea Zinc and Young Peon in South Korea; Padaeng in Thailand; and Gecamines in Zaire. Several of these are affiliated with companies discussed earlier: Black Mountain (Phelps Dodge) and Touissit and Djebel Aouam (Acec-Union Miniere).

### ***Recent Producer Mergers and Alliances***

*In* the late 1980s, the world lead and zinc industries went through a period of consolidation. Doe Run (United States) brought together the lead operations of Fluor and Homestake. Pasminco (Australia) was formed from CRA and NBHH. Metaleurop (France) was created through the merger of Penarroya and the lead and zinc operations of Preussag. Somewhat older are Acec-Union Miniere and the MG-MIM-Teck-Cominco-Asarco group. Acec-Union Miniere (Belgium) consists of Vieille Montagne, MHO, Asturienne, and Jersey Miniere. Interlocking ownership joins MG (West Germany), MINI (Australia), Teck (Canada), Cominco (Canada), and Asarco (United States). (See figure 4-6.) The group controls an estimated one-quarter of NSW primary refined lead production and 20 percent of primary slab zinc output. It has even greater shares in the mining sector.<sup>29</sup>

<sup>28</sup>Richard H. Singleton, "The Mineral Industry of Norway," *Minerals Yearbook*, vol. III, 1985 ed. (Washington DC: U.S. Department of the Interior, Bureau of Mines, 1987).

<sup>29</sup>Paulo de Sá, "Structural Changes and Price Formation in the Minerals and Metals Industry," *Resources Policy*, vol. 14, No. 4, December 1988, pp. 257-273.

Figure 4-6-Cross-Share Participation between Metallgesellschaft-MIM-Teck-Cominco-Asarco, 1990



SOURCE: Paulo de Sá, "Structural Changes and Price Formation in the Minerals and Metals Industry," *Resources Policy*, vol.14, no. 4, December 1988, pp. 257-273; updated by the Office of Technology Assessment, 1990.