Nonferrous Metals: Industry Structure

September 1990

OTA-BP-E-62
NTIS order #PB91-104919



Nonferrous Metals: Industry Structure

Background Paper



CONGRESS OF THE UNITED STATES
OFFICE OF TECHNOLOGY ASSESSMENT

Recommended Citation:

U.S. Congress, Office of Technology Assessment, ***Nonferrous Metals: Industry Structure-Background Paper, OTA-BP-E-62*** (Washington, d: U.S. Government Printing Office, September 1990).

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Foreword

The 1980s were turbulent for the domestic nonferrous metals industries. Many mines and plants were closed during the decade, because of a variety of factors including aging facilities, environmental regulations, and low metals prices. The corporate structures of the industries also changed drastically as companies bought, sold, and merged businesses in order to become more competitive.

OTA examined the copper sector of the nonferrous industry in its 1988 report ***Copper: Technology and Competitiveness.*** That report describes the conditions the copper industry faced during the early 1980s. It documents the steps U.S. copper companies took to improve their position in the mid- 1980s, and evaluates the industry's present and possible future status.

This paper, requested by the Subcommittee on Mineral Resources Development and Production of the Senate Cornrnittee on Energy and Natural Resources extends the analysis of the earlier report. This report profiles the structures of four domestic nonferrous metals industries (copper, aluminurn, lead, and zinc) and the changes they have undergone since 1980. The study also outlines the U.S. position in the world markets.

The study found that the four industries are not homogeneous. They are distinct with each having its own experiences, problems, and structure. The copper industry had many temporary mine and plant closures during the 1980s, but rebounded late in the decade as a result of cost cutting programs and high copper prices. Though there were major changes in copper mine and plant ownership, most of the shifts consolidated assets among existing producers. There were, however, major changes in the ownership of the companies themselves. The last aluminum smelter built in the United States opened in 1980. Since then, about 20 percent of U.S. capacity has closed. The four 'major' U.S. firms have emphasized the fabrication sector of the business in the United States and expanded their primary aluminum capacity overseas. In the lead industry, much of the mine and plant capacity changed ownership in the 1980s. kad production declined by about a quarter to a third in the various primary sectors of the industry. The secondary (recycled) lead sector, which now accounts for 65 percent of domestic lead production, is a major influence on the market. Much of the primary zinc industry also changed ownership during the decade. The zinc processing sector experienced the greatest decline of the four industries. Its decline started in the mid- 1970s. The outlook for lead and zinc has improved somewhat in recent years. Several new mines opened late in the decade. The Red Dog, Alaska mine (slated to open in 1990) will greatly increase the U.S. presence in lead and zinc mining industries.

OTA wishes to thank the reviewers for their generous help in ensuring the accuracy and completeness of this report. OTA, however, remains solely responsible for the contents of this background paper.



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Chapter 1
Introduction

The 1980s were turbulent for the domestic nonferrous metals industries. Many mines and plants were closed-some temporarily, some permanently-for a variety of reasons including aging facilities, environmental regulations, and low metals prices. The corporate structures of the industries also changed drastically during the decade. Companies bought, sold, and merged businesses in order to become more competitive. This report profiles four domestic nonferrous metals industries (copper, aluminum, lead, and zinc) and the changes they have undergone since 1980.

SCOPE

The report focuses on the primary sectors of the four industries, little discussion is given to the secondary (recycling) sectors. Unless noted otherwise, prices, costs, and expenditures are in nominal (current) U.S. dollars, and global production and consumption figures refer to the nonsocialist world (NSW).1 All tonnage figures are in metric tomes (1 metric tonne= 1.1 short tons = 2,204.6 pounds). Companies are usually identified by their common abbreviations. Their full names, headquarters locations, major nonferrous metals affiliates, and principal countries of operation are listed in appendixes B and C.

BACKGROUND

The dominant feature of the nonferrous markets in the past decade was the global slowdown in demand growth. Following the oil shocks of the 1970s, metals use grew at much slower rates than had been common earlier in the post-war period (see figure l-l). Consumption growth rates declined several percentage points for each of the four metals in this study. The annual growth rates in NSW consumption during 1950-74 and 1979-88 were as follows:

	1950-74	*1979-88*
Copper	**3.9%**	**1.1%**
Aluminum	**9.0%**	**2.3%**
Lead	**2.7%**	**0.5%**
Zinc	**3.9%**	**1.2%**

This long-term (secular) slowdown affected metals producers worldwide not just in the United States.

U.S. metals producers faced other challenges, in addition to the demand slowdown, during the 1980s. In some cases, these problems had their beginnings 20 or 30 years prior. Since World War II, the United States has seen its dominance in the production of many nonferrous metals diminish greatly. In 1950, almost half of the NSW'S output of refined copper, aluminum, and zinc, and over a quarter of its lead came from the United States.[2] The dominance of U.S. companies was made even greater by their many foreign affiliates. By 1980, the U.S. share for refined metal production had declined to 24 percent for copper, 36 percent for aluminum, and 8 percent for zinc. The U.S. share of the lead market increased to 28 percent, because of the opening of the Viburnum Trend in Missouri.

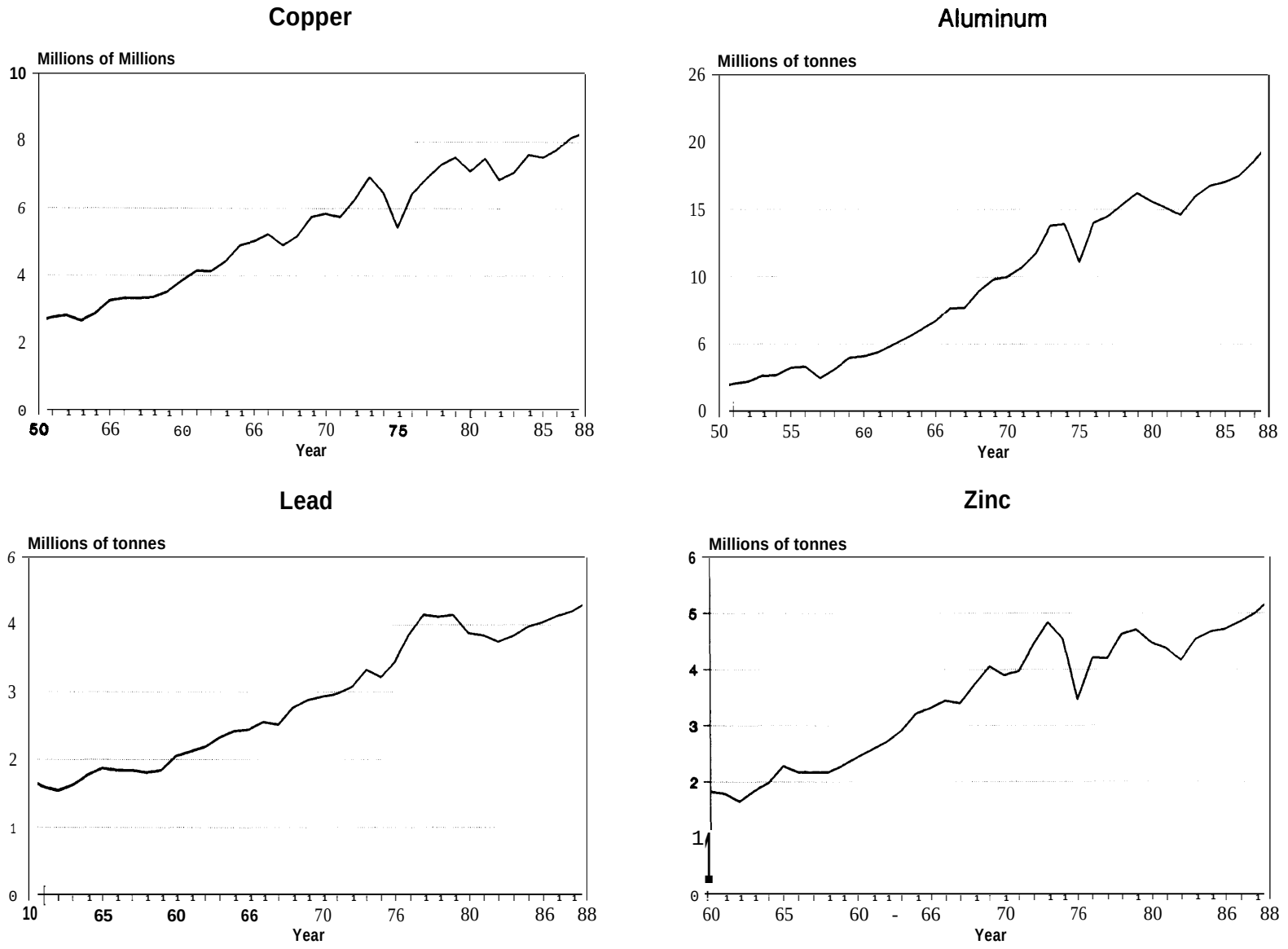
Production grew overseas faster than in the United States for a variety of reasons. New deposits were discovered in relatively unexplored foreign regions (e.g., Australia and Brazil). Processing plants were built overseas to keep costs low, to fiulfill countries' development plans, and to be near growing markets. For example, the development of abundant low-cost power lured aluminum~ production to Australia, Canada, Brazil, and Venezuela. The rebuilding of the war torn countries, and the general economic development of others, caused the overseas markets for metals to grew faster than the North American market.[3]

[1]The NSW comprises all countries with market economies (including Yugoslavia). It excludes the Centrally Planned Economies: Albania, Bulgaria, China, Cub% Czechoslovakia, East Germany, Hungary, Kampuchea, North Korea, Laos, Mongolia, Poland, Romania, the Soviet Union (U.S.S.R.), and Vietnam.

[2]Tables showing the largest NSW mine and metal producing nations in 1950, 1960, 1970, 1980, and 1988 appear in app. A.

[3]These countries did not all, however, become large end-users of the metal they consumed. Their metals fabrication sectors (the principal markets for metals) were developed for the purpose of making products for both domestic use and export.

Figure I-1-Nonsocialist World Consumption of Copper, Aluminum, bad, and Zinc, 1950-88



SOUROE: MefdSf8UsUa (wioue leeues), **Metaflgeaelfeohaft Akliengeeellaohaft.**

U.S. dominance was also weakened by the iiagrnentation of the metals markets. Many companies independent of U.S.-based multinationals began producing nonferrous metals. Among these were State-owned operations and custom smelters/refiners.[4] These companies complicate the markets because they have goals that often diverge from those of the traditional integrated producers. The industry was also shaken up by the entrance of non-mining firms (e.g., oil companies).

There was also direct market intervention (stockpile transactions and price controls) taken by the U.S. Government. Such actions, along with the establishment of floating exchange rates, caused metals prices to become more volatile. This made planning more difficult and the business generally more risky.

High production costs also plagued the U.S. industry. In the copper and zinc industries, the United States was in danger of becoming a marginal producer. Labor, energy, and environmental compliance costs increased during the 1970s especially. Productivity at U.S. mines and plants had not increased enough to offset the increased costs. Domestic facilities were mostly older and in great need of modernization.

COPPER

The United States is currently the NSW'S largest copper refiner, and second largest miner and primary smelter. Most of the production comes from Arizona, New Mexico, Utah, Michigan, and Montana. The principal foreign competitors are in less developed countries (Chile, Zambia, Zaire, and Peru). Except in Peru, the largest companies in these countries are state-owned.

In the 1980s, the domestic copper industry experienced many difficult years when prices and production levels were both low. Prices ranged from $0.66 to $0.77flb during 1982-86. U.S. primary copper production remained in the 1.0 to 1.2 million tonnes per year (tpy) range during 1982-87. The market began recovering in 1987. In 1989, prices rose to $1.31/lb and production increased to 1.5 million tonnes. The production levels at the end of the 1980s were comparable to those of the late 1970s, except in the smelting sector which had declined signicantly (see table l-l). Over the 1979-89 period, production was up 4 percent at mines, down 16 percent at smelters, down 3 percent at primary refineries, and up 7 percent at secondary plants. In comparison, production elsewhere in the NSW increased between 13 and 20 percent in the various primary sectors and 41 percent in the secondary sector during 1979-88 (see table 1-2).

Four major new domestic copper-producing mines opened during the decade (see table l-l). Five mines closed permanently and many more were closed temporarily because of low prices, strikes, and modernization shutdowns. From March 1981 to January 1983,28 domestic mines closed or cut back production and U.S. mine capacity utilization hovered around 65 percent.[5] In the processing sector, five smelters and three refineries (electrolytic and fire refineries) closed permanently. No greenfield plants opened, but several existing facilities underwent substantial modernization.[6] Environmental regulations and aging facilities were major causes of the decline in this sector. The picture was more positive in the electrowinning sector, seven facilities opened, five closed, and many were expanded.

The number of companies involved in the U.S. copper industry declined during the 1980s. Large producers such as Anaconda Copper, Amax, Duval, Inspiration, Cities Service, and Noranda left the industry while only Montana Resources and Cox Creek Refining entered. Major changes occurred in the ownership of severaI of the major producers. Cyprus was spun off from Amoco in 1985. Magma was spun off from Newmont in 1987. Copper Range changed hands several times before it was bought by Metall Mining (a Canadian subsidiary of Metallgesellschaft) in 1989. Kemecott was acquired by SOHIO (a subsidiary of British Petroleum) in 1981 and then sold to London-based RTZ (the world's largest minerals firm) in 1989.

Five companies (Phelps Dodge, Magma, Cyprus, Kemecott, and Asarco) currently account for most of the primary copper production in the United

[4]Custom smelters/refiners process concentrates (or other intermediate materials) produced by other companies. The feed material is either bought or tolled. In the case of tolling, the material is processed for a fee, but does not change ownership.

[5]U.S. Congress, Office of Technology Assessment, *Copper: Technology and Competitiveness, OTA-E-367* (Washington DC: U.S. Government Printing Office, September 1988).

[6]There is, however, talk of building a new copper smelter in Texas.

Table I-l—Profile of U.S. Nonferrous Metals Industries, 1989 and 1990

Production and consumption in thousands of metric tonnes[a] (preliminary statistics)	Copper 1989	Copper Change from 1979	Aluminum 1989	Aluminum Change from 1979	Lead 1989	Lead Change from 1979	Zinc 1989	Zinc Change from 1979
Mine production	1,498	4%			408	–24%	278	–5%
	(smelter)		(refinery)					
Intermediate metal production	1,120	–16%	NA	NA	—	—	—	—
Primary metal production	1,477	-3%	4,030	–1 2%	396	-31%	251	4 7 %
Secondary production	477[c]	4%	1 ,931d	20%	790'	– 2%	11Oc	107Y0
Metal consumption	2,184	1%	NA	NA	1,228	–9%	1,063	IYO
Number of facilities operating 1990 and number opened/closed 1980-90°	1990	Change 1980-90	1990	Change 1980-90	1990	Change 1980-90	1990	Change 1980-90
Major mines	25	4/5	-_[b]	a	17	6/2	22	7/5
Smelters	8	0/8	6	0/3	4	0/2	4	0/3
	(electrolytic)							
Refineries			23	0/10	4	0/1	—	—
	(electrowinning)							

NOTES:
[a]SOURCES: U.S. Department of the Interior, Bureau of Mines, *Mineral Commodity Summaries 1990* and *Mineral Industry Surveys* (Washington, DC).
bus. production of metallurgical-grade bauxite is small.
[c]Refined metal recovered from Okt and new scrap.
[d]All products (metal, chemicals, etc.) recovered from old and new scrap.
[e]SOURCE: U.S. Department of the Interior, Bureau of Mines, *Minerals Yearbook* (Washington, DC), various issues.

Table 1-2—Profile of U.S. and Nonsocialist World Nonferrous Metals Industries, 1988

Production and consumption in thousands of metric tonnes	Copper 1988	Copper Change from 1979	Aluminum 1988	Aluminum Change from 1979	Lead 1988	Lead Change from 1979	Zinc 1988	Zinc Change from 1979
Mine production:								
United States	1,420	–2%	588	-68%	394	*–27%*	256	–13%
Rest of nonsocialist world	5,283	13%	86,891	1570	1,930	*-4%*	4,842	1170
Nonsocialist world	6,702	9%	87,479	13%	2,324	*–9%*	5,098	10940
Intermediate metal production:	(smelter)		(refinery)					
United States	1,043	*–22%0*	*5,105*	*–23%*	—	—	—	—
Rest of nonsocialist world	5,372	15%	26,277	28%	—	—	—	—
Nonsocialist world	6,415	7%	31,382	15%	—	—	—	—
Primary metal production:								
United States	1,406	*–7%*	*3,944*	–13%	392	–32%	241	*-49%*
Rest of nonsocialist world	5,179	*20%*	*9,909*	*3470*	1,861	2%	4,548	18%
Nonsocialist world	6,585	13%	13,852	16%	2,253	–6%	4,790	1O%
Secondary production:								
United States	453a	–1%	2,1 22b	32%	737a	–9%	89[a]	66%
Rest of nonsocialist world	1,003a	41%	3,275[b]	46%.	1,569a	1 1%	345'	9%
Nonsocialist world	1,456a	24%	5,397b	40%	2,306[a]	4%	434"	1770
Metal consumption:								
United States	2,214	2%	6,720	1 %	1,236	–8%	1,089	3%
Rest of nonsocialist world	6,051	13%	13,122	37%	3,090	11%	4,146	14%
Nonsocialist world	8,265	10%	19,842	23%	4,326	4%	5,235	11%

a Refined metal recovered from old and new Wrap.
[b]All products (metal, *chemicals,* etc.) recovered from old and new scrap.
SOURCE: *Metal Statistics 1978-1988,* Metallgesellschaft Aktiengesellschaft.

States. They are integrated producers that have been producing copper for many years. Most of their mines, smelters, and refineries are in the United States. Their strategies generally emphasize low-cost production and, except for Asarco, specialization in copper rather than broad-based minerals activities.[7] Over the last decade, these companies cut their costs drastically. Some of the measures (e.g., delayed maintenance) yielded short-term cost gains, but many resulted in permanent savings. Wage rates were renegotiated, and in some cases tied to metals prices. The number of workers was also cut. In addition, a great amount of money was invested to modernize mines and plants. As a result, the domestic industry is now relatively cost competitive and among the world's most modern. It is the leader in the use of low-cost solvent extraction-electrowinning (SX-EW) technology.

Little of the recent U.S. investment has gone into either exploration or research and development (R&D). Exploration has been limited because of the financial risk of building new mines, especially when several large new projects (e.g., Olympic Dam in Australia and Neves Corvo in Portugal) have recently come on stream and several others are expected soon (e.g., La Escondida in Chile and Salobo in Brazil). R&D efforts are also minimal. The general feeling is that technology transfers too quickly in the industry to allow any particular company to make exclusive gains from R&D. The problem is particularly acute in the area of product development. Little attention is paid to product differentiation. Copper is seen basically as a commodity, with consumers basing their purchase decisions almost solely on price.

Acid rain legislation tops the list of the industry's environmental concerns. U.S. copper producers feel they contribute little to overall sulfur dioxide (SO_2) emissions, and the associated acid rain, and therefore should not be subjected to more stringent regulations. They also argue that they have already invested greatly to reduce their SO_2 emissions under legislation enacted in the 1970s. Producers are also concerned about increases in energy costs that would result from energy utilities' compliance with potential regulations in this area.

ALUMINUM

The United States mines little bauxite, but is currently the NSW's second largest alumina refiner and largest aluminum smelter.[8] Except for one plant in the Virgin Islands, all of the domestic alumina refineries are located near the Gulf Coast. The smelter capacity is located primarily in the Pacific Northwest and the Ohio Valley, but also in the Carolinas, New York, and Texas. The major foreign producers are in Western Europe, Canada, Australia, Brazil, and Venezuela. Most of the industry's new capacity is being built in the latter four countries, because of their abundant, low-priced electricity. The cost and availability of electricity, which accounts for about one-third of primary aluminum production costs, are principal factors in the siting of new smelters and the competitiveness of existing smelters.[9]

The U.S. aluminum market went through several cycles during the decade. Prices fluctuated between $0.47/lb and $0.76/lb in the 1980-87 period, but ended the decade somewhat higher ($1.10/lb in 1988 and $0.89/lb in 1989). U.S. primary aluminum production fell as low as 3.0 million tpy (in 1986), but recovered to around 4.0 million tpy in 1988-89. Primary production in 1989 was 12 percent lower than that in 1979. Secondary production, however, was up 20 percent over the same period. In other NSW countries, primary aluminum production increased 34 percent and secondary production increased 46 percent during 1979-88.

During the decade, four alumina refineries and ten aluminum smelters closed. More smelters were closed temporarily at various times, because of low prices. The only new facility to open was the Mount Holly, South Carolina smelter which began production in 1980.

Three companies (Conalco, Anaconda Aluminum, and Revere Copper and Brass) left the U.S. industry during the 1980s. A fourth, Martin Marietta sold one of its smelters and leased the other to an

[7]Gary A. Campbell, "The Response of U.S. Copper Companies to Changing Market Conditions," *Resources Policy,* vol. 15, No. 4, December 1989, pp. 320-336.

[8]This report does not cover the U.S. bauxite mining sector. Most domestic bauxite goes for nonmetallurgical uses such as abrasives, chemicals, proppants, refractories, or specialty aluminas.

[9]Merton Peck (cd.), *The World Aluminum Industry in a Changing Energy Era* (Washington, DC: Resources for the Future, 1988).

independent producer. Six companies (Columbia Aluminum, Columbia Falls, Alcan, Vanalco, Ravenswood, and Northwest Aluminum) entered U.S. industry in the 1980s. A seventh (Ornet) was essentially new to the industry also. It was sold to its current owners, Ohio River Associates, in 1986.

The "U.S. majors" (Alcoa, Reynolds, Alumax, and Kaiser) operate almost two-thirds of U.S. smelter capacity. They are multinationals with aluminum smelters and fabricating plants all over the world. Except for Alumax, they all own bauxite mines and alumina refineries. Most of these companies' recent investment in the primary aluminum sector have been in overseas facilities. For example, Alcoa is investing in Australia, and Reynolds and Alumax are spending in Canada. In the United States, they are emphasizing the fabricating end of the business (cans, foil, packaging, architectural products, etc.).[10] All four companies invest heavily in R&D for these more value-added products.

The remaining one-third of U.S. aluminum smelter capacity is operated by two Canadian firms and seven 'independents. The Canada-based firms are Alcan and Noranda. The independents are Ormet, Southwire, Columbia Aluminum, Columbia Falls, Vanalco, Ravenswood, and Northwest Aluminum. Except for Southwire, all were formed in the 1980s.

Recycling is an important factor in the U.S. aluminum industry. The production of secondary aluminum consumes about 90 to 95 percent less energy than does primary aluminum. About 60 percent of secondary aluminum recovered from old scrap comes from used beverage containers (UBC). In 1988, the UBC recycling rate was about 55 percent in the United States. Most UBC is recycled by aluminum sheet producers, many of which are also primary aluminum companies. Industrial scrap is processed by secondary smelters. About 40 secondary aluminum producers are in operation in the United States.

Acid rain legislation, because of its effects on the electric utilities, is the principal environmental concern of the aluminum industry. All proposed SO_2 emissions regulations will raise costs at coal-based utilities to some degree. The extent to which the cost increases will be passed on to aluminum smelters is uncertain. The impact will be mitigated somewhat by the variable rate contracts that tie electricity rates to the price of aluminum. A U.S. Bureau of Mines study of 10 domestic smelters found that the various acid rain proposals would increase their electricity rates by 3.5 to 5.5 mills/kWh and increase their costs by an estimated 2.5 to 4¢/lb of aluminum.[11] The increases, however, are very site-specific. In Ohio and West Virginia, costs would increase *5.2* to 7.7¢/lb; in other regions, the effects would be smaller. Smelters tied to hydropower utilities would see minimal rate increases. The 10 smelters studied account for 90 percent of the aluminum capacity that is tied to coal-fried generating facilities-those most liable to experience cost increases from acid rain legislation.[12] They account for about half of domestic aluminum capacity overall.

LEAD

The United States is a major producer of lead. It currently ranks second in the NSW in mine output and first in refined lead production. The principal mines and plants are in southeastern Missouri's Viburnum Trend. There are additional lead-producing mines in Colorado, Idaho, Montana, and Alaska, and processing facilities in Montana and Nebraska. The main integrated foreign competitors are Australia, Canada, and Mexico. In addition, Peru is a major mining country, and Western European countries and Japan have large processing sectors.

The U.S. lead industry faced hard times in the mid-1980s. Lead prices started the decade at around $0.43/lb, fluctuated downward to $0.19/lb in 1985, and then recovered to the $0.35 to $0.49/lb range in 1987-89. Production of primary lead declined over the decade. During 1979-89, U.S. mine production declined 24 percent and primary metal production fell 31 percent. Secondary production declined in the early 1980s, but rose later in the decade to nearly match its 1979 level. In other nonsocialist countries,

[10] The majors have not, however, abandoned all of their domestic primary aluminum capacity. It helps them manage their business risk.

[11] The smelters studied were Sebree, KY (Alcan); Frederick, MD (Alumax); Mt. Holly, SC (Alumax); Badin, NC (Alcoa); Evansville, IN (Alcoa); Rockdale, TX (Alcoa); Hawesville, KY (Southwire); New Madrid, MO (Noranda): Hannibal, OH (Ormet); and Ravenswood, WV (Ravenswood). John B. Bennett, *The Potential Impact of Acid Rain Legislation on the Domestic Aluminum Industry, OFR* 58-88 (Washington, DC: U.S. Department of the Interior, Bureau of Mines, October 1988).

[12] U.S. Congress, Congressional Research Service, *Acid Rain Legislation and the Domestic Aluminum Industry,* CRS Report for Congress, 89-327 ENR, May 1989.

primary production held fairly steady and secondary production rose 11 percent during 1979-88.

Six new lead-producing mines opened during the decade.[13] 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.

Much of the U.S. primary lead industry changed ownership during the 1980s. Ten firms (Doe Run, Asarco, Cominco-Dresser, Montana Tunnels, Greens Creek, Washington Mining, Hecla, Bunker Hill Mining, Star-Phoenix Mining, and New Butte Mining) currently mine lead in the United States. Only Doe Run and Asarco operate smelting/refining facilities.

Cominco-Alaska will operate the new Red Dog zinc-lead mine in Alaska. The mine is slated to open in 1990. The project is a joint venture between Cominco (a Canada-based multinational minerals producer) and NANA (an Alaskan Native corporation) which owns the mineral rights to the property. Red Dog is being developed primarily for its zinc. However, at full capacity it will be the United States' third or fourth largest lead-producing mine and will increase domestic production by 16 percent over 1989 levels. The mine will ship its concentrates to British Columbia, the Far East, and Europe for processing.

Lead's health effects are the industry's most important environmental issue. Health concerns have weakened demand for the metal in some sectors (e.g., gasoline additives, indoor paints, and various building products). There is also concern regarding the health and safety of workers exposed to lead particulate during the production process. Most of the industry is not in compliance with the current National Ambient Air Quality Standards (NAAQS) particulate standard for lead.[14]

Compared with other metals industries, lead has a relatively easy time meeting the SO_2 emissions standards of the Clean Air Act. The economics of sulfur recovery are further aided by existence of large nearby sulfuric acid markets. However, one of the four existing primary smelters does not have an acid plant, and could be forced to close in the not-too-distant future under contemplated regulations.

Currently, about 65 percent of U.S. refinery output is secondary lead. Lead acid batteries account for 85 percent of total recycled lead material at domestic secondary plants. The major secondary smelters in the United States are RSR Corp., Pacific Dunlop/GNB Battery, Schuylkill Metals, Exide Corp. Battery, and Sanders Lead, which represent over 70 percent of domestic capacity. Environmental factors caused recycling to become more difficult in the 1980s. Spent lead batteries are classified by the U.S. Environmental Protection Agency (EPA) as hazardous waste under the Resource Conservation and Recovery Act (RCRA). Many scrap collectors and dealers refuse to handle batteries for fear of incurring liability under Superfund.[15] However, the integrated metal producers, battery manufacturers, and large independent smelters have backward integrated into this market segment to a large degree.

ZINC

The United States is a relatively small zinc producer. In the NSW, it ranks sixth in mine production, eighth in primary refinery production, and first in secondary output. The principal zinc mining State is Tennessee. It accounts for over half of U.S. production. Additional zinc-producing mines are located in Missouri, Colorado, Alaska, Idaho, Montana, New York, and Nevada. About 20 percent of total zinc production comes as a byproduct of Missouri lead mines, but most comes from mines where lead is of minor importance. Processing facilities are located in Tennessee, Pennsylvania, Oklahoma, and Illinois. The main foreign integrated producers are Canada, Australia, and Western European countries. In addition, Peru and Mexico are major mining countries, and Japan has a large processing sector. The major area for new primary zinc capacity is Australia.

[13] This includes the Red Dog zinc-lead mine, slated to begin full production in 1990.

[14] Raymond J. Isherwood et al., *The Impact of Existing and Proposed Regulations Upon the Domestic Lead Industry*, OFR 55-88 (Washington, DC: U.S. Department of the Interior, Bureau of Mines, 1988).

[15] Superfund is the common name for the Comprehensive Environmental Response, compensation, and Liability Act.

Zinc prices, unlike those of copper, aluminum, and lead, fluctuated upward during the 1980s. The price of zinc remained above its 1980 level of $0.36/lb for the entire decade. Prices rose their greatest in the later years, when they increased from $0.38/lb (1986) to $0.82/lb (1989). U.S. secondary production rose during the decade, but primary output fell. Compared with 1979 levels, U.S. production in 1989 was down 5 percent in mining, down 47 percent in primary slab processing, and up 107 percent in secondary slab processing. In other nonsocialist countries, production increased 11, 18, and 9 percent in the mining, primary slab, and secondary slab sectors respectively during 1979-88.

In the United States, one new zinc mine (Pierrepont) 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. Five zinc mines, and one zinc-producing precious metals mine, were permanently closed during the 1980s. In the processing sector, three smelter/refineries were closed permanently and no new ones opened.

As in the lead industry, much of the U.S. zinc industry changed ownership during the 1980s. Fourteen firms (Zinc Corp. of America, Jersey Miniere, Big River, Asarco, Alta Gold, Cominco-Dresser, Doe Run, Montana Tunnels, Greens Creek, Hecla, Washington Mining, Bunker Hill Mining, Star-Phoenix Mining, and New Butte Mining) currently produce primary zinc in the United States. Only the first three operate primary smelting/refining zinc facilities. All but Big River operate mines.

When it opens in 1990, the Cominco-NANA Red Dog mine will greatly boost the United States' stature as a zinc producer. At capacity, it will be the world's largest zinc mine and nearly double U.S. zinc mine production over 1989 levels.

The decline in the U.S. zinc industry during the last two decades has been more pronounced than in the copper, aluminum, and lead industries. Primary slab zinc capacity fell from 980,000 tomes in 1970 to 570,000 tonnes in 1980 to 320,000 tomes in 1988. The closures were the result of declining local supplies of concentrates, rising energy (primarily natural gas) costs , and environmental regulations.[16]

Compliance with environmental regulations does not appear to constitute a major competitive disadvantage to current U.S. producers .17 Of the four primary slab plants that remain, three are electrolytic plants which are relatively easy to modify to meet environmental standards.

[16]Gary A. Campbell, Anil Jambekar, and Brian Frame, "Zinc Processing in the USA: An Analysis of a Declining Industry," *Resources Policy, vol.* 12, No. 4, December 1986, pp. 317-334.

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

Chapter 2
Copper Industry

INTRODUCTION

Copper has been used in jewelry, utensils, weapons, and tools for thousands of years. Such objects were hammered from native copper-the naturally occurring pure metal-in areas around the Mediterranean Sea and Lake Superior as long ago as 6000-5000 BC. The metal was first smelted from ores around 4000-3500 BC. Ancient mines have been found in Israel, Cyprus, Spain, and Britain. The Industrial Revolution and the age of electricity created the need for a highly developed copper industry.

uses

Copper's excellent electrical conductivity makes it important for power, lighting, and communications. In addition, its strength, durability, malleability, and resistance to corrosion and fatigue make it useful in a variety of structural applications.

In the United States, the largest market for copper is the construction industry. An estimated 41 percent of domestic copper mill shipments went to this industry in 1988.[1] Uses there include electrical wiring, plumbing and heating, air-conditioning and refrigeration, and architectural applications (e.g., gutters and roof and wall cladding). The second largest market (22 percent of shipments) was the electrical and electronics industry for uses such as telecommunications, power utilities, industrial controls, business electronics, and lighting and wiring. Other major markets include the industrial machinery and equipment industry (14 percent), the transportation sector (12 percent), miscellaneous consumer goods (e.g., appliances, cooking utensils, jewelry, and objets d'art), military applications, coinage, pharmaceuticals, and chemicals.

Across all markets, copper is used primarily for electrical and electronic applications. Copper use in these applications accounted for 70 percent of apparent domestic consumption in 1988.[2]

Production Methods and Technologies

Modern copper production techniques were established around 1900. Until then, only very rich ores (those containing 5 to 30 percent copper) could be processed economically. The commercial exploitation of lower grade ores became possible with the development of precipitation and flotation technologies and large-scale mining and processing methods. Today, most copper comes from ores containing 0.5 to 2 percent copper.

Copper is produced primarily from sulfide minerals such as chalcopyrite ($CuFeS_2$), chalcocite (Cu_2S), bornite (Cu_2FeS_4), and covellite (CuS). Some production, though, is based on oxide minerals such as malachite ($Cu_2(OH)_2CO_3$), azurite ($CuSiO_3$), chrysocolla ($Cu_3(OH)_2(CO_3)_2$), and cuprite (Cu_2O). Copper ore may be mined by either open pit, underground, or solution mining methods. Open pit mines account for about 60 percent of nonsocialist world (NSW) production and 85 percent of U.S. production. Copper is extracted from the ore by two principal methods: pyrometallurgical (concentration-smelting-refining) and hydrometallurgical (leaching-solvent extraction-electrowinning).

The pyrometallurgical route is the more common production method. The first step, ore concentration, occurs at the minesite. It involves crushing, grinding, and flotation of the ore into concentrates which contain 20 to 30 percent copper. Concentrates are the crudest intermediate product that is marketed.

The next processing steps (roasting, smelting, and converting) are performed at the smelter.[4] Roasting is an optional step which is sometimes used to upgrade the concentrates. Smelting breaks down the

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[1] *Annual Data* 1989, COpper Development Association Inc. (Greenwich, CT).

[2] Janice L.W. Jolly and Daniel Edelstein, '' Copper," *Minerals Yearbook,* vol. I, 1988 ed. (Washington, DC: U.S. Department of the Interior, Bureau of Mines, 1990).

[3] U.S. Congress, Office of Technology Assessment, $C_{opper:}$ *Technology and Competitiveness*, OTA-E-367 (Washington, DC: U.S. Government Printing Office, September 1988). John G. Peacey, "Copper Metallurgy," *McGraw-Hill Encyclopedia on Science and Technology (New York:* McGraw-Hill, 1987). Janice L.W. Jolly, "Copper," *Mineral Facts and Problems, 1985* ed. (Washington, DC: U.S. Department of the Interior, Bureau of Mines, 1985).

[4] The term ''smelting'' commonly refers to all processes carried out at the smelter.

complex minerals to produce a liquid copper-sulfide matte (35 to 75 percent copper). There are four basic smelting technologies: flash, reverberatory, electric, and continuous.[5] Converting, usually carried out in a Pierce-Smith converter, oxidizes the matte into blister copper (98.5 to 99.5 percent copper). Environmental regulations and process economics make the control of sulfur dioxide (SO_2) gas a very important aspect of the various smelting processes. In recent years, concerns about the air quality impacts of reverberatory furnaces have led to the widespread adoption of electric and flash furnaces in the United States.

Most of the impurities remaining in the blister copper are removed at the refinery. First, the molten blister copper is fire-refined (to further reduce its sulfur and oxygen content) and then cast into anodes. The anodes are then electrolytically refined (electrorefined). They are hung vertically between cathode starter sheets in long tanks (cells) filled with an acidic copper sulfate solution. An electric current is run through the solution (between the electrodes) and the copper gradually corrodes from the anode and plates onto the cathode. The end product, cathode copper, is 99.99+ percent copper. Cathodes are melted and cast into wirebar or continuous bar stock (for wire manufacture), slabs (for mechanical use), or ingots (for alloying).

In the hydrometallurgical production route, copper is recovered from the ores using aqueous (water-based) solutions. This method is applied mainly to oxide ores, and to low-grade oxide and sulfide mine wastes.[6] It is a very low-cost method of producing copper. When mining costs are excluded (or nonexistent as in the case of waste dump leaching), copper can be produced for around $0.30/lb. In 1988, about 16 percent of domestic primary copper output was produced by hydrometallurgical techniques.

The first step, leaching, involves percolating sulfuric acid (H_2SO_4) through the ore or waste. The acid (leachate) dissolves the copper minerals and carries them away. The copper is recovered by solvent extraction and electrowinning (SX-EW).[7] In solvent extraction, an organic chemical that dissolves copper but not impurity metals is mixed with the leachate.[8] The organic solution collects the copper and is then treated with sulfuric acid (H_2SO_4) to strip the copper into an electrolytic solution. Copper is recovered from the electrolyte by electrowinning, a process similar in principal to electrorefining (described above). The main difference is with the anodes. Electrowinning uses inert (nondissolving) anodes since the copper is already in the electrolyte. Application of the electric current deposits the copper on to the cathode. The cathode copper is then stripped from the starter sheets (which are reused), and shipped to the rod mill or fabricator.

THE 1980s

The U.S. copper market started the 1980s in a shortage situation (see figures 2-1 and 2-2). In 1980, domestic primary copper production (1.2 million tonnes) was low and prices (averaging $1.01/lb) were high compared with previous years. Production increased in 1981, but then fell to the 1.0 to 1.2 million tonnes per year (tpy) range during 1982-87. Prices were also low in this period. They averaged $0.75/lb in 1982-83 and $0.67/lb in 1984-86. These prices were similar in nominal terms to those of the

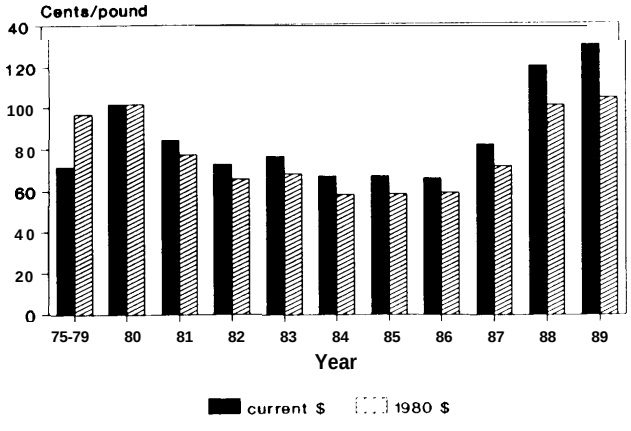
[5] Flash processes (Inco and Outokumpu) combine roasting and hearth smelting. The sulfide particles in the concentrates r-et with an air/oxygen mixture to produce a large proportion of the thermal energy needed for smelting. As a result, flash furnaces have relatively low fuel costs. Further, their waste gases are rich in SO_2, permitting economic pollution control. The reverberatory process was widely favored over the last 50 to 60 years because of its versatility; all types of material, lumpy or free, wet or dry, could be smelted. However, the reverberatory furnace has relatively high fuel requirements, and its sulfur dioxide gas is too dilute for economic conversion into sulfuric acid or treatment with other pollution control methods. The electric process uses an electrically heated hearth furnace that is similar in operation to the reverberatory furnace, but with more advantageous control of tbe effluent gases. The process makes limited use of heat generation from sulfide oxidation, and the heavy reliance on external energy can result in relatively high energy costs. Two continuous processes (Noranda and Mitsubishi) are in limited use. They combine roasting, smelting, and converting in one operation that produces blister copper directly from concentrates, while taking advantage of the heat generated by the oxidation of sulfides. The benefits of continuous processes include lower capital cost, reduced materials handling, low heat losses, very low energy requirements, economical sulfur dioxide gas recovery, and the ability to apply online computer controls to the entire copper-making process. Neither of these processes, however, has yet proven to be truly continuous. Their slags, which have high copper contents and must be recycled, can only be processed with auxiliary equipment.

[6] Roasting, a pyrometallurgical process, is sometimes used to convert sulfide minerals to more easily leachable oxides and sulfates.

[7] An older method of recovering copper from the leachate is the iron precipitation, or cementation, process. The pregnant leach solution flows through a pile of scrap iron/steel. Copper flakes and powder precipitate onto the steel surfaces, but are carried away under the force of the flowing solution. The copper is relatively impure, however, and subsequent treatment is required, usually through normal smelting and refining.

[8] Solvent extraction is largely confined to copper oxides. This includes naturally oc curring oxide ores and sul.tide ores that have been oxidized by the atmosphere (e.g., in waste dumps) or by roasting. Similar processes for sulfides and complex ores are still being developed.

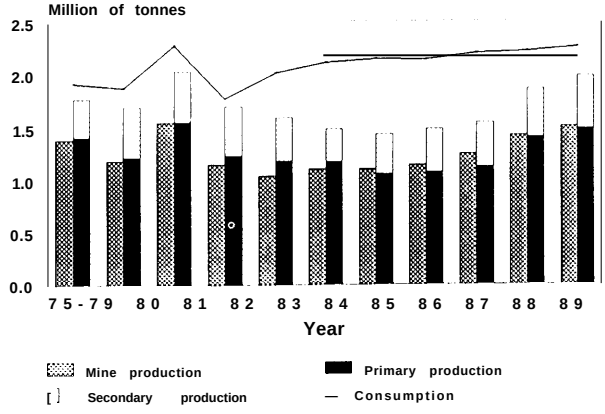
Figure 2-l-Copper Prices, 1975-89



NOTE: U.S. producers price—Cathode copper 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.

Figure 2-2—U.S. Copper 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.

1975-79 period, but about one-third lower in real (inflation adjusted) terms. The market began recovering in 1987. In 1989, production had reached 1.5 million tonnes and prices had risen to $1.32/lb in 1989.

U.S. production of secondary (scrap-based) copper followed a similar pattern to that of primary copper. It started the decade around 470,000 tpy, fell to 310,000 tomes in 1984, and then recovered to 500,000 tonnes in 1989. Over the entire decade, secondary material accounted for 26 percent of total U.S. refined copper production (compared with 20 percent in 1975 -79).9

The United States consumed 1.9 million tonnes of copper in 1980.[10] Consumption rose in 1981, but then fell to 1.7 million tonnes in 1982 (a recession year). In 1983, consumption increased even though production continued to fall. By 1985, consumption had risen to 2.1 million tpy. It has grown an average of 1.3 percent per year since. The difference between consumption and total refined production changed greatly over the decade. This gap, which is met with imports or inventory reductions, grew from 165,000 tpy in 1980-82 to 615,000 tpy in 1983-87. The gap narrowed somewhat in 1988-89.

For the nonsocialist world (NSW) as a whole, copper production and consumption were relatively stable during the 1980s (see figure 2-3). Over the period 1980-88, primary refined production grew at annual rate of 1.5 percent and consumption rose at a rate of 1.9 percent. Secondary production averaged 17 percent of total NSW refined copper production.

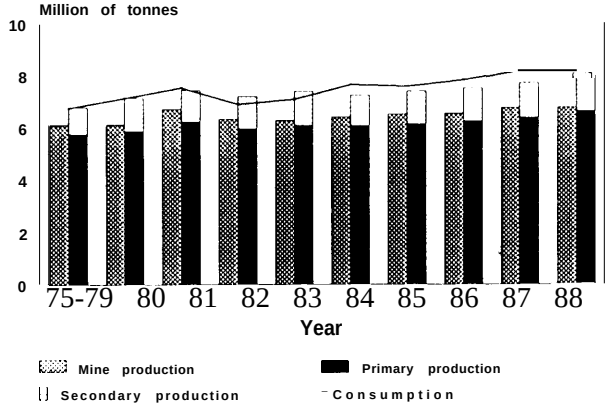
The openings, closings, and ownership changes that occurred in the U.S. primary copper industry during the 1980s are profiled in table 2-1. Three new copper mines (Troy, Pines Altos, Miami) opened during the decade. A lead mine (Casteel) which produces copper also opened. Five mines (Sacaton, Copperhill, Magma, New Cornelia, and Continental) closed permanently during the 1980s. Many more mines closed temporarily at some time during the 1980s because of low prices, strikes, and modernization shutdowns.

In the processing sector, five smelters and three refineries (electrolytic and fire refineries) closed. Environmental regulations and aging facilities were

[9]These figures represent the refried copper recovered from both new and old scrap. As such they overstate the amount of refined copper 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, 1.3 million tonnes of secondary copper were *recovered from* old scrap (5 19,000 tonnes) and new scrap (793,000 tomes), and *recovered as* refined metal (453,000 tonnes) and brass, foundry products, and other ''non-refined" products (861,000 tomes). Janice L. W. Jolly and Daniel Edelstein, "Copper," *Minerals Yearbook,* vol. I, 1988 ed. (Washington DC: U.S. Department of the Interior, Bureau of Mines, 1990).

[10]In this report, consumption is defined in terms of unmanufactured metal products. Consumption does not include the metal contained in imported manufactured products such as automobiles or electronics.

Figure 2-3—NSW Copper 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.

major causes of the decline in this sector. No greenfield plants were constructed, but several new facilities were built at existing sites (the Hayden smelter, the Sam Manuel smelter, and the White Pine refinery). There is talk, however, of building a new smelter in Texas in the early 1990s. The picture was more positive in the electrowinning sector, seven facilities opened and five closed. In addition, existing facilities were expanded. Electrowinning production grew from 118,000 tonnes in 1980 to 228,000 tonnes in 1988 and the expansion is continuing. During 1980-88, U.S. smelter capacity declined 36 percent to 1.2 million tonnes, electrolytic refining capacity fell 22 percent to 1.6 million tonnes, and electrowinning capacity rose 57 percent to 300,000 tonnes.

The number of companies involved in the U.S. copper industry declined during the 1980s. Large producers such as Amax, Anaconda Copper, Cities Service, Duval, Inspiration, and Noranda left the industry. All of their facilities, except for one mine and one refinery, were purchased by existing copper producers. Montana Resources and Cox Creek Refining were the only new companies to enter the industry. Major changes occurred in the ownership of many producers. Cyprus was spun off from Amoco in 1985. Magma was spun off from Newmont in 1987. Copper Range changed hands several times before it was bought by Metall Mining in 1989. Kennecott was acquired by SOHIO (a subsidiary of British Petroleum) in 1981 and then sold to RTZ in 1989.

PRODUCER PROFILES, 1990

Chile and the United States dominate all sectors of the primary copper industry: mining, smelting, and refining (see figure 2-4). They have been the industry leaders for much of this century. Japan, the third ranked smelting and refining country, has little mine capacity and relies on imports of concentrates to feed its industry. The medium-sized producers are Canada, Zambia, and Zaire. Together, these six countries control about two-thirds of the NSW primary copper output. The United States, Japan, and Western European countries are the largest secondary copper producers.

Less developed countries (LDCs) play a larger role in the copper industry than in the aluminum, lead, and zinc industries. Chile, Zambia, Zaire, Peru, Mexico, and the Philippines are involved in all aspects of the primary copper industry, not just the mining sector. In 1988, developing countries world accounted for 57, 48, and 39 percent of NSW mine, smelter, and refinery production respectively.

Copper production is a major part of some LDCs' economies.[11] Consequently, the governments of these countries keep tight control over, and often own, the production companies. In 1981,62 percent of LDC mine capacity was held by companies which were majority government owned.[12] The tendency for developing countries to run their industries for political as well as financial goals exacerbated the problems for the U.S. industry in the 1980s.

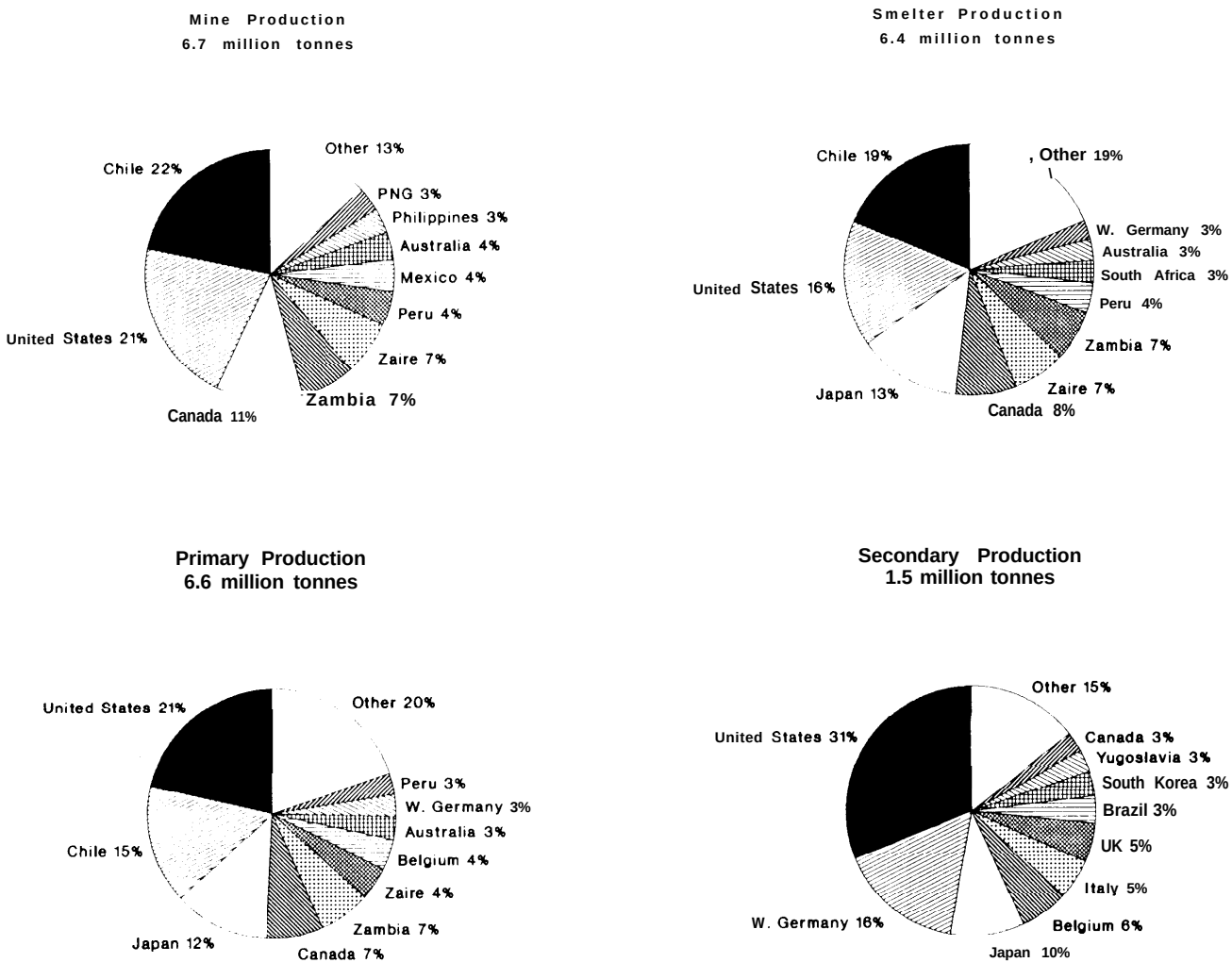
Chile, Peru, Zambia, Zaire, Indonesia, Australia, Papua New Guinea (PNG), and Yugoslavia belong to the Intergovernmental Council of Copper Exporting Countries (CIPEC).[13] Established in 1967, this trade association conducts marketing studies, dis-

[11] Copper accounted for 80 to 97 percent of the total export earnings of Zambia (1983-88),20 to 58 percent for Zaire (1981-83),41 to 50 percent for Chile (1983-89), 34 to 65 percent for Papua New Guinea (1983-89), and 13 to 22 percent for Peru (1983-87). International Monetary Fund (IMF), *International Financial Statistics.*

[12] Marian Radetzki, *State Mineral Enterprises (Washington* DC: Resources for the Future, 1985).

[13] Conseil Intergouvernemental des Pays Exporters de Cuivre.

Figure 2-4—NSW Copper Production, Country Profile, 1988



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

seminates information on copper developments, and seeks to promote expansion in the industry. During 1974-76, in the wake of the Organization of Petroleum Exporting Countries (OPEC) success in raising oil prices, CIPEC attempted to establish itself as a cartel. It tried, but failed, to stabilize then falling copper prices through production cutbacks. The group has discussed price stabilization numerous other times but has been unable to agree on a program. CIPEC's power to manage supply and stabilize markets has never been established.[14]

United States

The United States ranks as the first or second largest producer in all sectors of the NSW copper industry. Most U.S. producers are integrated from mining through to the refining stage. Several companies also have facilities to produce copper rod and other semi-manufactured products.

There are currently approximately 35 domestic copper mines in production. The 13 largest ac-

[14]U.S. Congress, Office of Technology Assessment, $C_{opper:}$ *Technology and Competitiveness*, OTA-E-367 (Washington, DC: U.S. Government Printing Office, September 1988).

Table 2-l—Profile of U.S. Primary Copper Production Industry, 1980 and 1990

	1980	1990	
Major mines:			
Ray, AZ	Kennecott	Asarco	Sold to Asarco 1986
Mission Complex, AZ	Asarco	Asarco	Comprises Mission, Eisenhower San Xavier, and Pima mines.
Eisenhower, AZ	Asarco-Anamax[ab]	Asarco	Anamax share sold to Asarco 1987; made part of Mission Complex
Pima, AZ	Cyprus-Utah Int'l[c,d]	Asarco	Sold to Asarco 1985; made part of Mission Complex
Troy, MT	—	Asarco[e]	Opened 1981
Silver Bell, AZ	Asarco	Asarco	
Sacaton, AZ..	Asarco	—	Closed 1983
Copperhill, TN	Cities Service	—	Closed 1987; sold to Tennessee Chemical 1982
White Pine, MI ... ,	Copper Range[f]	Copper Range[g]	Sold to Echo Bay 1984, Northern Copper (ESOP) 1985, Metall Mining 1989
Bagdad, AZ.....	Cyprus[c]	Cyprus	Note1
Sierrita, AZ.....	Duval[h]	Cyprus	Sold to Cyprus 1986; includes Sierrita and Esperanza mines-combined 1986
Miami, AZ.....	Inspiration	Cyprus	Note 2; includes inspiration and Ox Hide mines
Bluebird, AZ	Rachers Exp. & Dev.	Cyprus	Sold to Inspiration and integrated with Inspiration (Miami) mine 1984; Note 2
Twin Buttes, AZ.	Anamax[a,b]	Cyprus	Sold to Cyprus 1988
Pines Altos, NM.	—	Cyprus	Opened 1987; owned by Exxon until 1982; sold to Boliden 1982, Cyprus 1987
Mineral Park,AZ	Duval[h]	Cyprus	Sold to Cyprus 1986
Casa Grande (Lakeshore), AZ..	Noranda	Cyprus	Sold to Cyprus 1987; renamed Casa Grande 1987
Casteel (Viburnum #35), MO..,	—	DoeRun[i]	Opened 1984; owned by Fluor (St. Joe); later became Doe Run; see Table 4-1
Bingham Canyon, UT	Kennecot	Kennecott[j]	Modernization 1985-1987; Note 3
Carr Fork, UT	Anaconda Copper[b]	Kennecott[j]	Sold to Kennecott and integrated with Bingham Canyon mine 1985; Note 3
San Manuel, AZ..	Magma[k]	Magma	Note 4
Pinto Valley, AZ	Cities Service	Magma	Notes 5&4
Miami, AZ.....	—	Magma	Opened 1983; developed by Cities Service; Notes 5&4
Magma, AZ	Magma[k]	—	Closed 1982
Butte Mines, MT.	Anaconda Copper[b]	Montana Resources[l]	Sold to Montana Resources 1985; minority share sold to Asarco 1989
Morenci/Metcalf, AZ	Phelps Dodge	Phelps Dodge[m]	Minority share sold to Sumitomo 1985
Tyrone, NM	Phelps Dodge	Phelps Dodge	
Chino, AZ	Kennecott	Chino Mines[n]	Modernization 1981-84; Note 6
New Cornelia(Ajo), AZ	Phelps Dodge	—	Closed 1984
Continental, NM	Sharon Steel	—	Closed 1982
Smelters:			
Great Falls, MT..	Anaconda Copper[b]	—	Closed 1980
Hayden, AZ	Asarco	Asarco	Reverberatory furnace replaced with flash 1982-83
El Paso, TX.....	Asarco	Asarco	
Tacoma, WA	Asarco	—	Closed 1985
Hayden (Ray), AZ	Kennecott	—	Closed 1982; sold to Asarco 1986
Copperhill, TN....	Cities Service	—	Closed 1987; sold to Tennessee Chemical 1982
White Pine, MI...	Copper Range[f]	Copper Range[g]	
Miami (Globe), AZ	inspiration	Cyprus	Note 2
Garfield, UT.....	Kennecott	Kennecott[j]	Modernization 1985-87; Note 3
McGill NV.....	Kennecott	—	Closed 1983
San Manuel, AZ.	Magma[k]	Magma	Reverberatory furnace replaced with flash 1986-88; Note 4
Hildago, NM	Phelps Dodge	Phelps Dodge	
Hurley, NM.,...	Kennecott	Chino Mines[n]	Note 6
Douglas, AZ	Phelps Dodge	—	Closed 1987
Morenci, AZ....	Phelps Dodge		Closed 1985; minority share sold to Sumitomo 1985
Ajo, AZ	Phelps Dodge		Closed 1984
Texas City, TX...	—		Construction under consideration by Texas Copper, a joint venture led by Mitsubishi

Table 2-l—Profile of U.S. Primary Copper Production Industry, 1980 and 1990-Continued

1980	1990	
Refineries:		
Electrolytic and fire refining:		
Great Falls, MT. . . . . Anaconda Copper[b]		Closed 1980
Amarillo, TX . . . . . Asarco	Asarco	
White Pine, MI . . . . . Copper Range[f]	Copper Range[g]	Fire-refining process replaced with electrolytic 1982-86
Baltimore, MD . . . . . Kennecott	Cox Creek Refining[o]	Sold to Cox Creek 1986
Miami (Globe), AZ . . . . . Inspiration	Cyprus	Note 2
Garfield, UT . . . . . Kennecott	Kennecott[j]	Modernization 1985-87; Note 3
Hurley, NM . . . . . Kennecott		Closed 1984; Note 6
San Manuel, AZ . . . . . Magma[k]	Magma	Note 4
El Paso, TX . . . . . Phelps Dodge	Phelps Dodge	
Laurel Hill, NY. . . . . Phelps Dodge		Closed 1983
Carrolton, GA . . . . . Southwire	Southwire	
Electrowinnlng:		
Arbiter, MT , ... , , ... —	Anaconda Environ-Refining	Closed since 1977; to reopen 1990
Braithewaite, LA . . . . . Amax	—	Closed 1985
Hayden (Ray), AZ . . . . . Kennecott	Asarco	Sold to Asarco 1986
Miami (Globe) , AZ . . . . . Inspiration	Cyprus	Note 2
Casa Grande, AZ . . . . . Noranda	Cyprus	Sold to Cyprus 1987
Twin Buttes, AZ , ., ... Anamax[ab]	Cyprus	Closed 1985; reopened 1989; leased to Cyprus 1988
Bagdad, AZ . . . . . Cyprus[c]	Cyprus	Note 1
Sierrita, AZ . . . . . —	Cyprus	Opened 1987
Johnson, AZ . . . . . Cyprus[c]	—	Closed 1986; Note 1
Battle Mountain, NV , ... Duval[h]	—	Closed 1984
Sierrita, AZ . . . . . Duval[h]	—	Closed 1982
San Manuel, AZ . . . . . —	Magma	Opened 1986; Note 4
Pinto Valley, AZ . . . . . —	Magma	Opened 1981; Note 4
Miami, AZ , ... Magma[k]	Magma	Note 4
Tyrone, NM . . . . . —	Phelps Dodge	Opened 1984; operated by the Burro Chief subsidiary
Morenci, AZ . . . . . —	Phelps Dodge	Opened 1987
Chino, NM . . . . . —	Chino Mines[n]	Opened 1988; Note 6
Globe, AZ . . . . . Ranchers Exp. & Dev.	—	Closed 1982

NOTES:
[a]Anamax was a subsidiary of Anaoonda Copper and Amax.
[b]Anaconda Copper was a subsidiary of Atlantic Richfield (Arco).
[c]Cyprus was a subsidiary of Standard Oil of Indiana (Amoco).
[d]pi[ma] was owned 75% by Cyprus and 25% by Utah International.
[e]Asarco owns 75 percent of the Troy, MT mine.
[f]Copper Range was a subsidiary of Louisiana Land.
[g]Copper Range is a subsidiary of Metall Mining Corp, a subsidiary of Metallgesellschaft.
[h]Duval was a subsidiary of Pennzoil.
[i]D[oe] Run is a subsidiary of Fluor.
[j]Kennecott is a subsidiary of RTZ.
[k]Magma was a subsidiary of Newmont.
[l]Montana Resources is a subsidiary of Washington Corp. The Butte Mines are owned by Montana Resources and Asarco.
[m]The Morenci/Metcalf mine and smelter are 85% owned by Phelps Dodge and 15% by Sumitomo.
[n]Chino Mines is a subsidiary of Phelps Dodge and Mitsubishi.
[o]Cox Creek Refining is partially owned by Mitsubishi 20%, Southwire 200/& and Ha[stead Industries 20%.
[1]Cyprus spun off from Amoco 1985.
[2]Cyprus acquired Inspiration's copper mines, smelter, refinery, and rod mill 1988.
[3]Kennecott was acquired by Standard Oil (SOH IO), a majority-owned subsidiary of British Petroleum (BP), 1981. Kennecott was held under the BP America subsidiary. BP became full owner of SOHO and merged Kennecott with Amselco to form BP Minerals America 1987. Most of BP's metals assets were sold to RTZ 1989.
[4]Magma spun off from Newmont 1987.
[5]Cities service sold Pinto Valley and Miami mines to Newmont 1983. Newmont combined them with its Magma subsidiary 1988.
[6]Mitsubishi acquired a one-third share of Kennecott's Chino Mines Division (including the Chino mine and the Hurley smelter and refinery) 1981. Kennecott sold its share of Chino Mines to Phelps Dodge 1986.

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

counted for more than 95 percent of production in 1989.[15] A small amount of copper is produced as a byproduct of gold, lead, silver, or zinc at an additional 30 mines. The largest copper-producing States are Arizona, New Mexico, Utah, Michigan, and Montana. Mining in the United States is characterized by a high proportion of surface mines (85 percent of capacity), low feed grade (average 0.65 percent copper), and high wage rates. Although most operations produce at least some byproduct, revenues from byproducts are on the average fairly low. The number of surface mines, the use of modem

[15]U.S. Department of the Interior, Bureau of Mines, *Mineral Commodity Summaries*, 1990 ed. (Washington, DC: 1990).

technology, and the establishment of good management practice make U.S. mines and mills among the most productive in the world in terms of workhours per tonne of ore. In this regard, U.S. facilities improved dramatically in the 1980s.

There are currently eight domestic primary smelters in operation. Reverberatory smelting furnaces are used at El Paso (Asarco) and White Pine (Copper Range). The one electric furnace smelter, Miami (Cyprus), has been among the most costly of the domestic plants to operate because of high electricity rates. Newer, more efficient, flash furnaces are used at Hayden (Asarco), San Manuel (Magma), and Chino and Hidalgo (Phelps Dodge). The Noranda continuous process is used at the Garfield (Kennecott) smelter. Smelting in the United States is characterized by stringent air pollution controls and, until recently, an unattractive sulfuric acid market. [16]

There are currently eight electrolytic and twelve electrowinning refineries in operation operating in the United States. In 1988, approximately 16 percent of U.S. refined production came from the electrowinning process. Leaching and SX-EW technologies, because of their low costs, were an important aspect in the U.S. industry's financial turnaround in the late 1980s.

The United States is the world's largest secondary copper producer. The secondary sector accounted for about a quarter of total domestic production in 1988. There are five secondary smelters, two electrolytic refineries, and six fire refineries in operation.

Seven domestic companies (Phelps Dodge, Cyprus, Magma, Asarco, Montana Resources, Cox Creek, and Southwire) and two European firms (RTZ and Metallgesellschaft) have major holdings in the primary copper industry in the United States (see figure 2-5). In addition, two Japanese firms (Mitsubishi and Sumitomo) have partial holdings in U.S. mines.

Phelps Dodge

Phelps Dodge is North America's largest, and the world's second largest, copper miner.[17] In 1988, it produced one-third of the copper mined and about a one-quarter of the copper smelted and refried in the United States. It is primarily a copper company, but it makes other products as well. The corporation is organized into two major divisions. The Mining division includes the company's domestic copper operations (from mining through rod production, marketing, and sales), the foreign mining operations and investments, and the exploration programs. In 1986-88, this division accounted for 62 percent of the company's revenues and 81 percent of its earnings. The other division, Industries, runs most of the corporation's manufacturing operations. It includes Columbian Chemicals (a carbon black and synthetic iron oxide company), ACCURIDE (a steel wheel manufacturing company), and the Phelps Dodge Magnet Wire Co. It also includes interests in companies that produce wire, cable, and rod in 14 foreign countries.

Phelps Dodge's major domestic mines are Morenci/Metcalf in Arizona and Chino and Tyrone in New Mexico. Each mine has an associated electrow inning plant. The company owns smelters at Hurley (Chino) and Playas (Hildalgo) in New Mexico, and a refinery and rod mill at El Paso, Texas. Phelps Dodge has holdings in several foreign operations that produce primary copper. It owns 16 percent of the Southern Peru Copper Corp. (SPCC) which runs two copper mines and a smelter in Peru. Smaller amounts of copper are produced by the wholly owned Ojos del Salado copper-gold mines in northern Chile and the 45-percent-owned Black Mountain lead-silver-zinc-copper mine in South Africa. Phelps Dodge also has a feasibility study underway for the La Candelaria deposit in Chile. This mine could possibly be producing 100,000 tpy by the mid- 1990s.

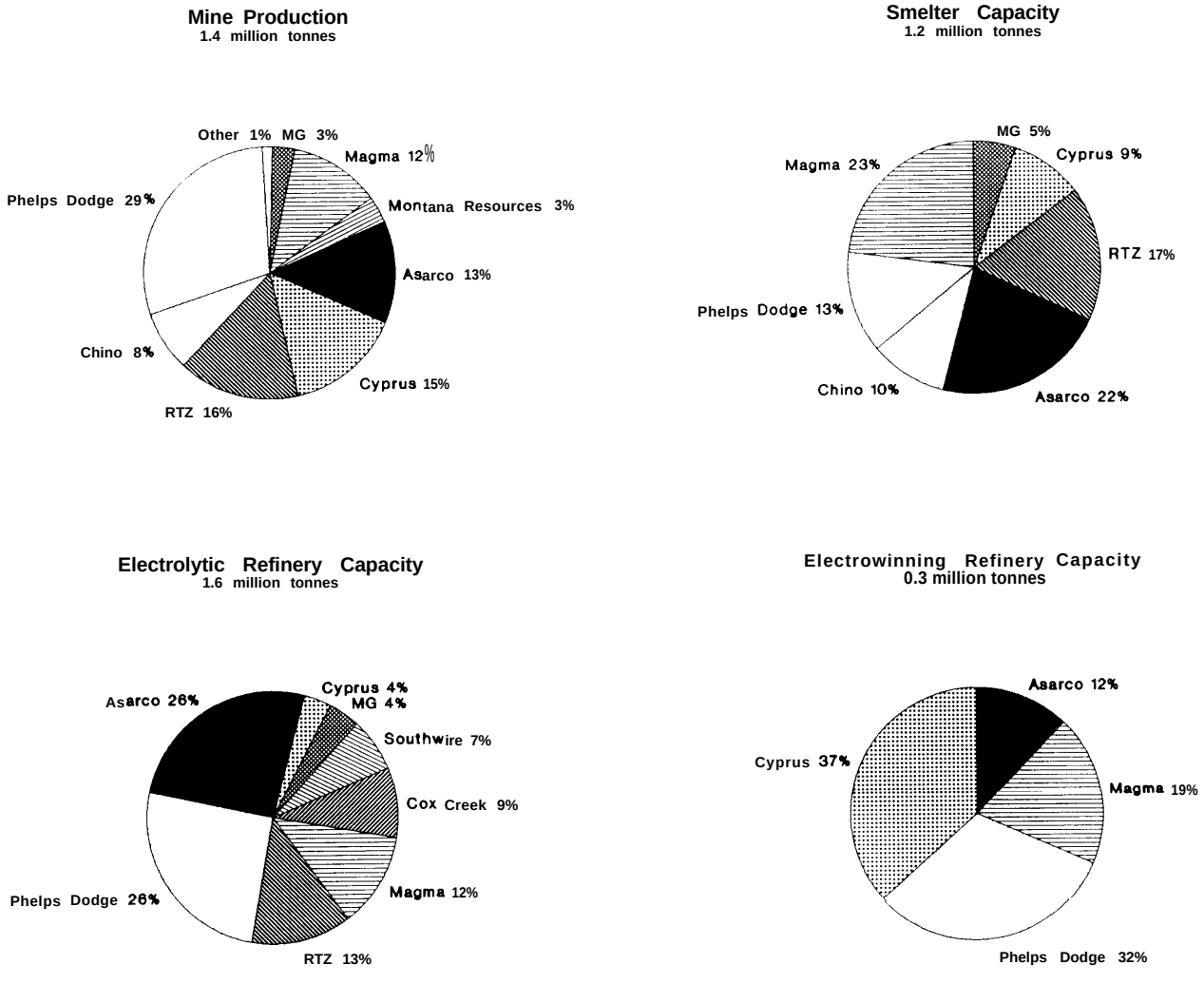
The company's domestic mines produce much more concentrate than its smelters can handle. In 1986, Phelps Dodge sold 15 percent of the Morenci mine to Sumitomo to divert some of the concentrate to Sumitomo's smelters, and more importantly, to raise cash for restructuring programs. Mitsubishi owns one-third of the company's Chino mine and smelter.[18]

[16] Sulfuric acid is recovered by the air-pollution control processes in copper smelting and is often sold as a byproduct or used in SX-EW operations.

[17] Among all NSW mining companies, Phelps Dodge ranks well behind Codelco (Chile), but just ahead of Gecamines (Zaire) and ZCCM (Zambia). It is the largest private producer, these other leading producers are all state-owned. In several years though, the company will rank behind RTZ in mining, but not in the smelting/refiig sector.

[18] A prior owner, Kennecott, sold a one-third interest in all of the output of Chino Mines to MC Minerals, a joint venture between Mitsubishi Corp. and Mitsubishi Metal Corp. Phelps Dodge purchased the remaining two-thirds from Kennecott in 1986.

Figure 2-5--U.S. Copper Industry, Company Profile, 1988



NOTE: Phelps Dodge's mine production includes 40,400 mt produced for other's accounts. Asarco's mine production includes 5,200 mt produced for other's accounts.

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

The Sumitomo and Mitsubishi shares together account for about 5 percent of total U.S. mine production.[19] Even after Mitsubishi takes its portion of the mine output, Phelps Dodge still has surplus concentrates. In 1988, the smelters handled only about 70 percent of the company's concentrate share, the rest was toll smelted. Production should be more in balance when the Tyrone mine closes in the early 1990s.

Phelps Dodge has invested heavily (and continues to do so) in SX-EW facilities. In 1988, the company processed 80,800 tonnes (18 percent of its mine output) by the SX-EW method. That figure may rise to 40 percent in the 1990s.

Phelps Dodge has established itself in the copper fabrication sector. It is the world's largest producer of copper rod (the basic feed for the electrical wire

[19]Mitsubishi does not have processing facilities in the United States. The U.S. concentrate is shipped to smelters in Japan. The company has talked, however, of building a new smelter in Texas which would presumably process its U.S. concentrates as well as those from the La Escondida project in Chile.

and cable industry). The domestic continuous cast copper rod mills are in El Paso, Texas and Norwich, Connecticut. The rod production exceeds the company's internal sources of refined copper, so the supplies are supplemented with purchases.

Phelps Dodge is credited with leading the U.S. copper industry out of the 1980s recession. It was the first company to deal aggressively with its unions, cut its costs, and return to profitability .20 Its business plan, in effect since 1984, has three elements. The frost is to reduce production costs in the copper operations and to enhance their profit margins rather than to maximize production. The second is to build and strengthen the non-copper businesses to help the company better withstand copper price swings. In this regard, the company stresses significant market share, internationally competitive costs and quality, specialized engineering capabilities, and stable earnings and cash flow. The third element is to strengthen the financial structure of the corporation.[21]

Kennecott/RTZ

Kennecott (owned by London-based RTZ) is the second largest copper mining company, and the fourth largest smelting and refining company, in the United States. The company's Bingham Canyon mine and its Garfield smelter and refinery are located in Utah. The Bingham Canyon mine, which underwent a $400 million modernization from 1985-87 under the ownership of BP America, is the largest copper mine in the country. RTZ obtained these facilities in 1989 when it purchased most of British Petroleum's (BP) metals mining division. The operation was renamed Kennecott (after the company that ran the mine for much of this century).

RTZ is one of the world's largest metal mining corporations. It produces copper, aluminum, iron ore, lead, molybdenum, tin, zinc, gold, and silver at various subsidiaries and related companies throughout the world. It also produces energy (coal, oil, and uranium) and industrial products including borax, silica, specialty chemicals, fabricated and engineered products, and construction materials and services. In 1987, prior to the BP acquisition, RTZ's earnings profile was: industrial sector (63 percent), metals sector (24 percent), and energy sector (13 percent).[22] RTZ's companies operate under a decentralized management style. The chief operating units are left to manage themselves under strategic guidelines that are agreed to every two years.[23]

RTZ's foreign copper holdings include Bougainville (PNG), Highland Valley (Canada), Palabora (South Africa), Somincor (Portugal) and ER&S (Australia).[24] It also has a 30 percent stake in the 300,000 tonne per year (tpy) Escondida project in Chile. With its acquisition of BP and its interests in these major new mines, RTZ will be the largest private copper mining company in the world (surpassing Phelps Dodge) in several years. It will be a somewhat smaller presence in the smelting/refining sector.

Cyprus

Cyprus is the third largest domestic copper mining company, but is smaller in the smelting and refining sectors. It has mines at Bagdad, Sierrita, Miami, Twin Buttes, Casa Grande, and Mineral Park in Arizona and Pines Altos in New Mexico. About a third of the mine production is oxide ore. The company has leaching and SX-EW facilities at five of its mines. It also has a roaster at Casa Grande which is used to prepare sulfide ore for leaching and SX-EW processing. In addition, there is a smelter, refinery, and a rod plant at Miami (Claypool), Arizona; and a rod plant in Chicago, Illinois. Until 1988, when Cyprus acquired the Miami facilities from Inspiration Copper, most of the company's copper concentrates were toll smelted under short-term contracts. Now, about half of the concentrates are processed at the Miami smelter or the Casa Grande roaster. The remainder are smelted at Magma's San Manuel plant under a long-term contract.

Cyprus, once the mining subsidiary of Amoco, was spun off as an independent company in July

[20]Phelps Dodge led the U.S. industry's drive to lower wages and relax work rules. In 1983, Phelps Dodge continued production despite a prolonged strike at its facilities. Workers at the company's Arizona mines (at that time Morenci and New Cornelia) and El Paso refinery voted against continued union representation in the fall of 1984.

[21]Phelps Dodge Annual Report, 1988.

[22]RTZ Annual Report, 1987.

[23]American Mining Congress, *AMC Journal* (Washington DC: October 1989).

[24]Olympic Dam in Australia is part of BP, not RTZ. The tWO companies t erminated their agreement regarding the sale of Olympic Dam in late 1989.

1985. Since then it has grown through a very aggressive acquisitions program. All of its copper properties, except Bagdad, have been purchased since the spinoff. It has acquired properties from Duval, Noranda, and Inspiration Copper. The company keeps its labor costs low by insisting prior to its acquisitions that the facilities be closed and the workers be terminated. When Cyprus takes possession of (and restarts) the mine or plant, it rehires the workers it needs without union contracts.

Cyprus is strongest in the mining sector of the minerals business. Besides copper, Cyprus produces molybdenum, lithium, zinc, silver, gold, coal, and industrial minerals. It is the largest domestic producer of molybdenum, which it mines as a primary product in Nevada and Idaho and recovers from the copper ores at Sierrita (coproduct) and Bagdad (byproduct). The molybdenum processing facilities are in New Jersey. Cyprus acquired Foote Mineral, the largest NSW producer of lithium, from Newmont in 1988. The lithium mines are in Nevada and Chile, and the processing facilities are in Virginia, Pennsylvania, Tennessee, North Carolina, and Chile. Cyprus began recovering zinc and silver, as well as copper, from the Pines Altos mine in New Mexico in 1989. The company is evaluating a zinc-silver deposit in northern Mexico and a beryllium deposit in Texas.

Copper and coal have been at the center of Cyprus' business. During 1986-88, these two products accounted for about 80 percent of sales. However the proportions have changed significantly. In 1986, 50 percent of sales was from coal and 30 percent was from copper. In 1988, the proportions were reversed.

Asarco

Asarco is the second largest U.S. smelter and refiner and fourth largest miner.[25] It has copper mines at Ray and the Mission Complex in Arizona and at Troy in Montana. In addition, it *owns* half of the Butte, Montana mine. It has smelters at Hayden, Arizona and El Paso, Texas, and a refinery at Amarillo, Texas. Of the U.S. copper producers, Asarco is perhaps the most active in foreign projects. It is the majority shareholder (52 percent) in SPCC, the Peruvian copper mining and smelting concern. It also owns (through Medimsa) about 30 percent of Mexicana de Cobre which runs the La Caridad copper mine and Nacozari smelter in Mexico. Asarco also has ties to the Australian concern MINI, which owns copper facilities at Mt. Isa and has interests in base metal operations all over the world. Asarco owns 19 percent of MIM, and MIM owns 25 percent of Asarco. This link is a passive relationship that does not involve operational control.

Asarco was originally a smelting and refining company. However, in recent years it has become more involved in the mining sector to ensure its supply of concentrates. It got caught short on its concentrate supplies in the 1980s and has been buying mines to prevent this from happening again. The company thinks "the custom smelting and refining business has limited growth potential because there are fewer mines and mining companies today than in the past" and plans to "continue to make investments to increase its own mine production and expand ore reserves."[26] When the expansions are complete (in 1992), Asarco expects to have the capacity to provide all of the feed required by its copper smelters, compared to less than 25 percent in 1985. In 1989, Asarco joined with Montana Resources in the operation of the Butte, Montana copper mine. Asarco also has a large project underway to modernize its El Paso, Texas smelter.

Magma

Magma is the third largest domestic copper smelter and refiner and fifth largest miner. It had been a subsidiary of Newmont until 1987, when it was spun off. The company's operations are characterized by their physical proximity and technological interaction with one another. All the facilities are located in Arizona. Magma has two mining/milling/leaching complexes (San Manuel and Pinto Valley), three SX-EW facilities, a smelter and refinery (San Manuel), and one rod plant (San Manuel).

In 1989, Magma produced 22 percent of its copper by leaching and SX-EW methods. The company has excess smelting, refining, and rod making capacity. In contrast to Asarco, it is striving to develop its position as a custom smelter. The new flash furnace at San Manuel has a capacity of more than 1 million tpy of concentrates (about 270,000 tpy of blister copper) and is the largest copper smelting furnace in the world. It was scheduled to finish its commissioning period at the end of 1989. In 1989, tolling

[25] Asarco is also a major lead and zinc producer (see chs. 4 and 5).

[26] Asarco Annual Report, 1988.

accounted for 27 percent of Magma's refined copper production.

In 1989, Magma sold 65 percent of its copper as continuous cast rod, down from 93 percent in 1988. The company is decreasing its rod capacity to focus on producing cathode (primarily for Asian markets). It sold its Chicago rod plant to Cyprus in December 1989.

Magma is primarily a copper company, but it produces some molybdenum disulfide, gold, and silver. The company's strategy stresses modernization (e.g., the capital investment in San Manuel) and marketing (e.g., product quality, technical service, and customer relationships).

Montana Resources

Montana Resources, a smaller copper mining company, operates the historic Continental pit in Butte, Montana. In 1985, Washington Construction purchased the Butte operations from Anaconda Copper (a subsidiary of Arco) intending to salvage them for scrap. After conferring with Anaconda's former general manager, however, Washington Construction determined that the mine and mill could reopen profitably. The State and local governments, eager to see the operation contributing to the economy once again, procured credit lines, granted tax cuts, and quickly approved the necessary permits. The company obtained a $0.12/lb reduction in the transportation and refining costs Anaconda had paid to ship the concentrate by rail to California and have it processed in Japan. The local power company granted lower rates for electricity. Finally, the number of workers was cut almost 50 percent, and the top wage was reduced from $22 to $13/hr. As a result, when the East Berkeley Pit reopened early in 1986 as Montana Resources, it was reportedly mining copper for $0.58/lb, compared to Anaconda's $0.97/lb.[27] In 1989, Asarco purchased 49.9 percent of a new partnership that owns and operates the Montana copper properties.

Copper Range/Metallgesellschaft

Metall Mining, a Canadian subsidiary of Metallgesellschaft (MG) bought the Copper Range mine, smelter, and refinery in Michigan in 1989. The high-cost underground operation had at various times in the 1980s been owned by Louisiana Land, Echo Bay, and Northern Copper (an Employee Stock Option Plan). MG (based in Frankfurt, West Germany) is a large metals trading company whose other copper interests are minority holdings in Cominco (Canada) and Norddeutsche Affinerie (West Germany). The Michigan refinery was converted from the fire-refining process to the electrolytic process in the 1982-86 modernization program.

Cox Creek

Cox Creek began full production at its Baltimore, Maryland refinery and rod mill (formerly owned by Kennecott) in 1988. The company has no mine or smelting capacity. It purchases blister and scrap (for anode production), anode (for cathode production), and cathode (for rod production). Most of the primary feed is imported. Mitsubishi, a partner in the venture, supplies some of the raw material for cathode and rod production. Other partners include Southwire and Halstead Industries.

Southwire

Southwire operates a refinery in Carrolton, Georgia. It produces copper from both primary and secondary source material.

U.S. Interests in Other Countries

Several U.S. firms that do not have domestic primary copper facilities are involved in copper projects overseas. Exxon operates the Disputada mine and smelter in Chile. Freeport McMoRan owns 85 percent of the Ertsberg mine in Indonesia. Cerro Copper (part of the Marmon Group) and Newmont have interests in SPCC in Peru.[28] Amoco owns 30 percent of the Ok Tedi mine in Papua New Guinea, USX until recently held equity in Prieska in South Africa. In 1989, the mine closed and USX sold its interest,

Chile

Chile is the United States' strongest competitor in the copper business. It ranks first in mine and smelter production and second in the refining sector. Copper mining began in Chile in the 1850s. After several periods of growth and decline, the country became a consistent producer early in the 20th century. Chile exports 97 percent of its copper production, two-thirds in the form of refined copper. Its primary

[27] "There's a Gleam in the Eye of Copper Producers," *Business Week,* 1986.

[28] Cerro Copper has a secondary copper smelter in Sauget, Illinois.

markets for refined copper are Europe (about 50 percent), Asia (20 percent), and the United States (15 percent).

Codelco, owned by the Chilean government, controls about three-quarters of the country's capacity. It is the world's largest copper company, operating four major mines (Chuquicamata, El Teniente, El Salvador, and Andina) with a combined capacity of about 1.1 million tpy.[29] Current expansion programs are expected to increase the capacity by 27 percent (300,000 tpy) by the early 1990s.[30] Codelco also has three smelter/refinery complexes (Chuquicamata, Caletones, and Potrerillos).

ENAMI, another government-owned company, operates four concentrators, two smelters, and a refinery. The company accounts for about 18 percent of Chile's smelter capacity and 25 percent of its refinery capacity. The ENAMI facilities process concentrates from small and medium-sized independent mines and surplus materials from the Codelco mines.

Most private copper production in Chile is run by foreign interests. These companies have been attracted by Chile's moderately rich ores, favorable investment climate, well-developed mining infrastructure, and low paid and highly skilled work force. Exxon operates the Disputada mines and smelter. Anglo American of South Africa has a majority interest in the Mantes Blancos mine, smelter, and refinery. Phelps Dodge runs the small Ojos del Salado copper-gold mine in northern Chile and is exploring the La Candelaria deposit. BHP (Australia), RTZ (U.K.), Mitsubishi and Nippon Mining (Japan), and the World Bank have invested in the La Escondida project. La Escondida ''the hidden one' is slated to come on stream in the early 1990s with a capacity of 320,000 tpy. It is the world's largest new copper project.

Chile's long-term competitiveness is being challenged by declining ore grades. Chilean ore grades, though still higher than average, are falling faster than those elsewhere in the world. The decline is especially pronounced at Chuquicamata where the ore grade was 2.12 percent in 1980, but is projected to fall to l.0 percent by 2000. Codelco has addressed this decline through capacity expansion and exploitation of oxide resources.[31] The strategy has been to expand ore processing capacity enough to keep total refined copper output (and market share) constant or expanding. Central to this plan are the exploitation of oxide reserves from Mina Sur and the Chuquicamata pit, plus the leaching of waste dumps and low-grade sulfide ores.[32] The divestment has been substantial; Codelco has spent $300 to $400 million per year since 1984 for capital improvements and expansions. 33

Japan

Japan's copper mining industry is very small, but its smelting/refining sector has ranked in the NSW top three since 1970. The industry was built in the 1960s to lessen dependence on foreign supplies and to capture the added value of raw materials processing. Despite having such a large industry, Japan is still a net importer of refined copper. It imports about a quarter of its needs, primarily from Zambia, Chile, and the Philippines. Exports of refined copper are small.

To feed its industry, Japan has had to import enormous quantities of concentrates.[34] In fact, to ensure supplies of concentrates, the Japanese supported the development of mines in the Philippines, PNG, Indonesia, and elsewhere. During 1985-88, Japanese smelters imported an average of 3.1 million tonnes of ores and concentrates. The major suppliers were Canada (29 percent), the United States (14 percent), the Philippines, Chile, Papua New Guinea, Indonesia, and Australia. Approxi-

[29]Chuquicamata and El Teniente are the two largest copper mines in the world.

[30]*Financial Times* Mining *International Yearbook 1989* (Chicago, IL: St. James Press, 1989).

[31]Chile has a vast reserve of oxide resources and a climate that tends to oxidize the wastes and tailings from sulfide operations. Thus leaching and SX-EW have great potential in Chile. Leaching operations produced approximately 90,000 tonnes in 1986; their capacity is expected to triple by 2000.

[32]Drexel, Burnham, Lambert, *Special Copper Report,* December 1983.

[33]Janice L.W. Jolly and Daniel Edelstein, ''Copper, '' *Minerals Yearbook, vol.* I, various editions (Washington, DC: U.S. Department of the Interior, Bureau of Mines).

[34]The tariff structure in Japan (high for refined copper, but low for concentrates) has allowed Japanese smelters to outbid others for feed concentrates, and has been the source of trade friction.

mately 60 percent of the copper concentrate traded in 1986 was shipped to Japan.[35]

Six firms (Nippon Mining, Onahama, Sumitomo, Mitsubishi, Hibi Kyoda, and Dowa) are engaged in both smelting and refining in Japan. A seventh (Mitsui) is involved in refining only. Given the interests of Mitsubishi and Dowa in Onahama and of Mitsui in Hibi Kyodo, the effective control of Japan's smelting capacity is Nippon Mining (26 percent), Mitsubishi (26 percent), Sumitomo (16 percent), Dowa (12 percent), and Mitsui (10 percent). The percentages are similar for the refining sector.

Most, but not all, Japanese smelter capacity is located on the coast. This greatly facilitates the delivery of concentrates and the shipping of copper and sulfuric acid to their markets. About 60 percent of the capacity is based on flash furnace technology. Reverberatory furnaces account for most of the rest.

In the 1980s, Japan sought new joint projects to counter the tight concentrate markets and production cutbacks by traditional suppliers. These new ventures included projects in Colombia and Chile and equity positions in the United States. Mitsubishi acquired a one-third interest in Chino Mines (including the Chino mine and Hurley smelter and refinery) in 1981. Sumitomo acquired a 15 percent share of the Phelps Dodge Morenci/Metcalf mine in 1985. In addition, Japanese firms are expected to receive much of the copper (in the form of concentrate) from the La Escondida project in Chile when it goes into production.[36]

Canada

Canada, a medium-sized copper producer, ranks third in NSW mine production and fourth in smelter and refinery production. The country's mine output is greater than its smelter capacity, so it is a net exporter of concentrates. Canada exports over a third of its concentrate production (primarily to Japan) and over half of its refined production (mostly to the United States and Europe).

About three-quarters of Canada's mine production comes from five producers; Highland Valley and BHP-Utah in British Columbia, Falconbridge and Inco in Ontario, and Hudson Bay in Manitoba. Highland Valley (jointly owned by Cominco, Rio Algom, Teck, and Highmont) is the largest. It has no associated smelting and refining capacity, and sells most of its concentrate to Japan.

In general, Canadian mines are noted for their large quantities of co-products and byproducts (e.g., nickel, gold, silver, zinc, and molybdenum). About 20 percent of copper mine production comes as a byproduct of the Inco and Falconbridge nickel operations in Ontario's Sudbury district.

There are four companies (Noranda, Inco, Falconbridge, and Hudson Bay) involved in Canada's smelting and refining sector. Noranda with its Quebec operations (the Gaspe and Home smelters and the Canadian Copper Refiners division) is the largest. The company has little copper mine capacity, but is a major custom smelter and refiner. In 1989, Noranda and Trelleborg acquired full control of Falconbridge which has mining, as well as smelting and refining, facilities in Canada. With the acquisition, Noranda effectively controls an estimated 55 percent of Canada's smelting capacity and 65 percent of its refinery capacity.

Zambia and Zaire

The central African copper industry was developed in the 1910s and 1920s by colonial interests. The British operated in Zambia (then Northern Rhodesia) and the Belgians were based in Zaire (then the Belgian Congo). Shortly after Zambia and Zaire gained independence in the 1960s, their industries were nationalized.

Both countries export nearly all of their copper. Zambia's exports are mostly refined copper and are destined for Europe, Japan, and India. Zaire exported 6 percent of its copper as concentrates, 51 percent as blister (primarily to Belgium), and 43 percent as refined copper (mostly to Europe) in 1985-88.

All Zambian copper facilities are run by the state-owned Zambia Consolidated Copper Mines (ZCCM). The major mines are Nchanga, Mufilira, and Nkana. The ores are very rich (averaging 2.0 percent copper). Zambia's developed ore reserves are declining quickly and are expected to be depleted by early next century. Large undeveloped reserves exist, however. Recently, Zambia has supplemented

[35]World Bureau of Metal Statistics data.

[36]J.C. Wu, "The Mineral Industry of Japan," *Minerals Yearbook*, vol. III, 1985 ed. (Washington, DC: U.S. Department of the Interior, Bureau of Mines, 1987).

its mine production by toll smelting Zairean concentrates. ZCCM runs three smelters, four refineries, and three electrowinning facilities. Almost a quarter of Zambia's refined production comes from leach and electrowinning operations.

The state-owned Gecamines operates Zaire's principal mines, Dikuluwe/Mashamba, Kov, and Kamoto. The ores average 4.1 percent copper and are the richest copper ores mined in the world. Zaire is less involved in the processing sector than is Zambia. Gecamines does, however, run a smelter and two refineries.

The copper industries in Zaire and Zambia share many operating characteristics and problems. They both, for example, produce large amounts of by-product cobalt. Also, most of their copper output is exported, because the regional market for the metal is small. Transportation is a particularly important factor to these industries. The mines are remote and the transportation network to the distant seaports is cumbersome and unstable. Rail transportation in the region may become more reliable in coming years, because of improving prospects for political stability in southern Africa. However, the investment required to renovate the railroads will be great. Zambia and Zaire also have been plagued with internal political strife, hard currency shortages, power outages, and the acute threat of Acquired Immune Deficiency Syndrome (AIDS). These factors make it difficult to get and keep skilled expatriate personnel and to obtain spare parts for maintenance of the mining equipment.

Peru

Peru is a medium-sized copper producer which exports 90 percent of its production. During 1985-88, Peru exported 18 percent of its copper as concentrates (to Japan and West Germany), 28 percent as blister (mostly to Japan and the United Kingdom), and 54 percent as refined copper (to Europe, the United States, and Japan).

Peruvian production is dominated by the Southern Peru Copper Corp. (SPCC) open pit mines at Cuajone and Toquepala and smelter at Ilo. SPCC is owned by four U.S. companies-Asarco, Cerro Copper, Phelps Dodge, and Newmont. The venture accounts for about 60 percent of Peru's production.

There are also numerous smaller operations in Peru, some state-owned and some private, that mine complex silver-copper-lead-zinc ores primarily for the silver. State-owned Centromin runs a smelter and refinery at La Oroya to process its own concentrates as well as those from private mines. Minero Peru, also stated-owned, runs a refinery at Ilo. Peru's perennial economic, political, and weather problems make foreign investment there generally risky.

Mexico

Mexico produces refined copper for domestic uses and exports surplus concentrates. The United States (primarily Magma) is Mexico's largest customer for concentrates.

There are two major Mexican copper operations: Mexicana de Cobre and Cananea. Mexicana de Cobre, which is partially owned by U.S.-based Asarco, runs the La Caridad mine and the Nacozari smelter. The company accounts for about 55 percent of Mexico's mine production and 65 percent of its smelter capacity. Cananea, owned by the government, runs a mine and smelter. The company has been slated to be sold under a privatization effort, but efforts in this regard have failed thus far. The privatization is made even more contentious, because the mine is a sensitive national symbol. The mine's 1906 strike helped trigger the Mexican Revolution.[37] Cobre de Mexico runs the country's only refinery-the Atzcapotzalco plant in Mexico City. The company has no mines or smelters.

Australia

Australia exports about a quarter of its concentrate production and almost 40 percent of its refined production. MlM's Mt. Isa complex in Queensland dominates the domestic industry. The complex includes a mine (with very rich ore, 3.3 percent copper) and a smelter. The company also has a refinery at Townsville. The Electrolytic Refining and Smelting Co. of Australia (ER&S) runs a smelter/refinery at Port Kembla. The company is partially owned by RTZ. Australia's capacity recently rose with the opening of the 55,000 tpy Olympic Darn (Roxby Downs) project. The operation, which includes amine, smelter, and refinery, is owned by Western Mining and BP.

[37]Larry Rohter, "Feelings Running High as Copper Mine Is Shut," *New York Times,* Aug. 30, 1989.

The Philippines

The Philippines is a major exporter of copper concentrates. In the early 1980s, nearly all of its copper was exported as ores and concentrates. Now, about half of the production is exported as concentrates (mostly to Japan) and the other half is exported as refined copper.

Philippine copper production is dominated by the Atlas mines (Lutopan, Carmen, and Biga). Atlas accounts for about 40 percent of the country's mine production. Other companies include Maricalum, Marcopper, North Davao, Benguet, and Lepanto. PASAR runs the country's only smelter and refinery.

Papua New Guinea (PNG)

PNG began mining copper in the early 1970s. Japan helped finance the PNG mines in order to feed its smelters. All of PNG's production is exported as concentrates. About 40 percent of the concentrates are sent to Japan and 30 percent are sent to West Germany.

Two companies produce copper in PNG: Bougainville and Ok Tedi. Bougainvillea, accounted for three-quarters of production in 1988. It was shutdown in May 1989, because of sabotage actions protesting the mine's location on ancestral lands.[38] It is not expected to reopen soon, if ever. Ok Tedi began production in 1987. Its capacity is about 600,000 tpy of concentrates, or roughly 200,000 tpy copper. However, the operation been plagued with problems and has yet to operate near its design capacity. Ok Tedi is owned by Amoco (United States), BHP (Australia), several West German fins, and the government of PNG.

South Africa

South Africa is a smaller copper producer which exports about two-thirds of its production. During 1985-88, the country exported 9 percent of its copper as concentrates, 46 percent as blister, and 44 percent as refined copper to Europe and Japan.

The major South African producer is the Palabora operation with its mine, smelter, and refinery in the Transvaal near the Mozambique border. Palabora (partially owned by RTZ) accounts for about 80 percent of South Africa's copper production. It also produces uranium and zirconium. O'okiep runs a copper mine and smelter in Cape Province near Namibia.

West Germany

West Germany is a major copper smelting and refining country, but its mine production is small. It imports nearly all of the concentrates needed to feed the smelting industry. The major sources during 1985-88 were PNG (34 percent), Mexico (19 percent), and Chile (10 percent). West Germany also imports about 55 percent of the refined copper it consumes. The principle sources in 1985-88 were Chile (24 percent), Poland (18 percent), and Zaire (15 percent).

The major West German primary copper smelter is run by Norddeutsche Affinerie in Hamburg. The firm is owned by MG, MIM, and Degussa.

Belgium

Belgium is a major copper refining country but has no mining or primary smelter capacity. It that imports nearly all its blister and anode copper. Over one-half of the blister comes from Zaire (a former colony). South Africa and Sweden accounted for about 11 and 9 percent of imports respectively in 1985-88. Belgium's sole primary copper producer is Metallurgic Hoboken-Overpelt (MHO), a subsidiary of Acec-Union Miniere. It runs the refinery at Olen.

Other Countries

Other large copper mining companies around the world include: Boliden (Sweden), Freeport Indonesia (Indonesia), Rio Tinto Minera (Spain), and Somincor (Portugal). Other major smelting and refining operations include: Boliden (Sweden), Caraiba Metais (Brazil), BICC (United Kingdom), IMI Refiners (United Kingdom), Korea Mining & Smelting (South Korea), Outokumpu (Finland), and RTB Bor (Yugoslavia).

38 "An Audacious Rebel in Papua New Guinea Shakes Copper Market," *Wall Street Journal*, Jan. 2, 1990.

INTRODUCTION

Aluminum is the newcomer among the metals covered in this study. It was initially isolated as an element in the 1820s and first produced commercially in the 1880s.

Uses

Aluminum is the most widely used nonferrous metal. Its light weight, corrosion resistance, ease of recycling, and high electrical/thermal conductivity make it useful in a variety of applications. The largest market is the containers and packaging sector (beverage and food cans, foil, etc.). In the United States, this sector accounted for 27 percent of aluminum use in 1988. The other major markets are the transportation sector (21 percent), buildings and construction (18 percent), and electrical uses (9 percent).[1]

Production Methods and Technologies

Aluminum is the second most abundant metal element (after silicon) in the Earth's crust. It can be recovered from many minerals (e.g., clays, anorthosite, nepheline syenite, and alunite), but is produced most economically from bauxite, an impure form of alumina (Al_2O_3).[3] Approximately 90 percent of all bauxite is produced from surface mines. To extract the aluminum, the ore is crushed, washed, and dried (at the minesite) and then refined and smelted.[4]

The refining step produces pure alumina from bauxite. The Bayer process, discovered in 1888, is the principal refining method. The bauxite is crushed and ground, then digested in hot (280 to 450° F) caustic soda (NaOH) solution. The alumina minerals in the ore react with the caustic soda and dissolve as sodium-aluminate. Most of the impurities in the ore precipitate out as "red mud" which is removed by countercurrent recantation and filtration. The solution is then seeded with starter crystals and agitated to crystallize out alumina hydrate. This material is then calcined in kilns (to remove the water) and the result is pure alumina.

The smelting process reduces the alumina to aluminum. Modern processes are based on those discovered independently by Hall and Héroult in 1886. Alumina is dissolved in a molten cryolite (Na_3AlF_6) bath contained in carbon-lined steel cells (pots). In each pot, a direct current is passed through the bath (between a carbon anode and the carbon bottom of the cell) to reduce the dissolved alumina into aluminum. Molten aluminum collects at the bottom of the pots and is siphoned off into large crucibles. The aluminum (averaging about 99.8 percent purity) is poured directly into molds to produce foundry ingot or further refined/alloyed to make fabricating ingot. Scrap aluminum may be added to the melt either at this last stage or when the ingot is remelted at the foundry or fabricating facility.

The smelting process is continuous. Alumina is added, anodes are replaced, and molten aluminum is siphoned off without interrupting current in the cells. A potline may consist of 50 to 200 cells with a total line voltage of up to 1,000 volts at current loads of 50,000 to 225,000 amps. Electricity use in today's smelters is 6 to 8 kWh/lb of aluminum.[5] Electric power is one of the most costly raw materials in aluminum production.

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[1] Patricia A. Plunkert, "Aluminum," *Minerals Yearbook,* vol. I, 1988 ed. (Washington, DC: U.S. Department of the Interior, Bureau of Mines, 1990).

[2] Allen S. Russell, "Aluminum," *McGraw-Hill Encyclopedia on Science and Technology (New* York, NY: McGraw-Hill, 1987). Frank X. McCawley and Luke H. Baurngardner, 'Aluminum," *Mineral Facts and Problems, 1985* ed. (Washington DC: U.S. Department of the Interior, Bureau of Mines, 1985).

[3] The bauxite ores used t. produce aluminum metal typically contain 40 to 60 percent alumina (Al_2O_3) along with 1 to 15 percent silica (SiO_2), 7 to 30 percent hematite (Fe_2O_3), 1 to 5 percent titania (TiO_2), and 12 to 30 percent combined water. Nonmetallurgical grades of bauxite are used to produce abrasives, refractories, and chemicals.

[4] Unlike the other metals in this study, aluminum is refined before it is smelted.

[5] Though the basic process of aluminum smelting is 100 years old, the technology has improved steadily. Just after World War II, about 12 kWh of electricity was required to produce a pound of aluminum.

THE 1980s

The U.S. aluminum market started the 1980s on a good note (see figures 3-1 and 3-2). In 1980, domestic primary aluminum production (4.7 million tomes) was high and prices (averaging $0.76/lb) were high compared with the late- 1970s. The market went through several cycles during the decade. Prices fluctuated between $0.47 and $0.76/lb in the 1980-87 period, before ending the decade somewhat higher ($1.10/lb in 1988 and $0.89/lb in 1989). U.S. production of primary aluminum also fluctuated, but never rose above its 1980 level. It fell to around 3.3 million tonnes per year (tpy) in 1982-83 and 3.0 million tpy in 1986, and then rose to about 4.0 million tpy in 1988-89. The 1989 output was 13 percent lower than that of 1980, but comparable to the levels of the late- 1970s.

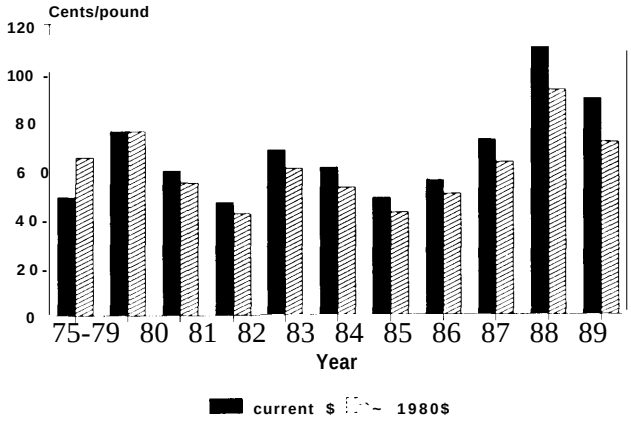
Secondary production (from old and new scrap) rose about 40 percent during the decade. Most of the growth occurred in 1987-89. This category represented about one-third of total U.S. aluminum production during the decade.[6]

Us. aluminum consumption also went through several cycles during the decade. Consumption fell from 6.1 million tonnes in 1980 to 5.3 million tonnes in 1982. It then fluctuated between 6.0 to 6.2 million tpy during 1983-86 and 6.4 to 6.7 million tpy during 1987-89.

The nonsocialist world (NSW) aluminum market experienced more muted cycles than those that occurred in the United States (see figure 3-3). After the 1982 recession, NSW aluminum production and consumption grew fairly steadily. In 1988, primary production was 13.8 million tonnes (up 8 percent from 1980), secondary production was 5.4 million tonnes (up 40 percent), and consumption was 19.8 million tomes (up 27 percent).

The openings, closings, and ownership changes that occurred in the U.S. primary aluminum industry during the 1980s are profiled in table 3-1. The Mount Holly smelter in South Carolina (which opened in 1980) is the most recent aluminum facility to be built in the United States. During the decade, 4 alumina refineries and 10 aluminum smelters closed. More

Figure 3-l—Aluminum Prices, 1975-89



NOTE: U.S. spot market price-primary aluminum ingot. 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.

were closed temporarily at some time during the 1980s, because of low prices. All of the permanently closed refineries and smelters were in the southern United States (Texas, Louisiana, Alabama, Arkansas, and Tennessee). During 1980-88, U.S. refinery capacity declined 29 percent to 5.1 million tonnes of alumina and smelter capacity declined 20 percent to 4.0 million tomes.

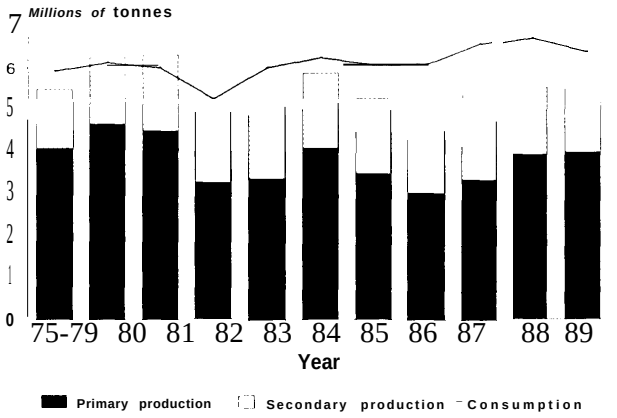
Amax (through its Alumax subsidiary) became a major aluminum producer during the 1980s. The company grew by building the Mt. Holly smelter and by purchasing Pechiney's shares of Intalco and Eastalco in 1983. After consolidating its position, Alumax sold about a quarter of each of its plants to raise money to expand in Canada.

Kaiser experienced several ownership changes in the 1980s. The company was acquired first by Alan Clore, a British investor, and then by Maxxam.

Three companies (Conalco, Anaconda Aluminum, and Revere Copper and Brass) left the U.S. industry during the 1980s. Another company (Martin Marietta) decreased its presence in the industry by selling one of its smelters and leasing the other to an independent producer. Six companies (Columbia Aluminum, Columbia Falls, Alcan, Vanalco, Ravens-

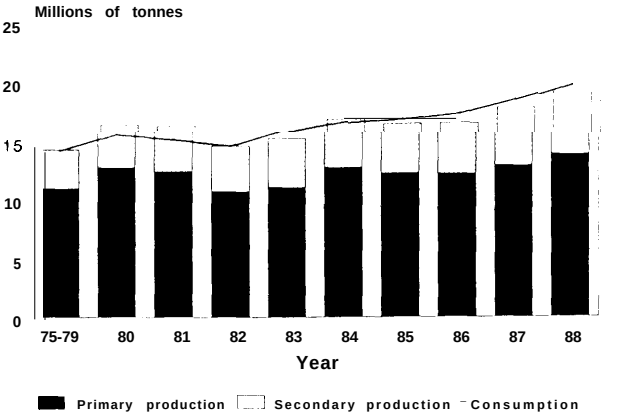
[6]These figures represent the total aluminum recovered from both new and old scrap. As such they overstate the amount of refined aluminum that is actually entering the manufacturing stream. Old scrap comes from discarded products, new scrap is waste from fabricating and other manufacturing processes. In 1988,2.1 million tonnes of secondary aluminum were *recovered from* old scrap (1.0 million tomes) and new scrap (1.1 million tonnes), and *recovered as* refined metal (2.1 million tonnes) and other "non-refined" products (37,000 tonnes). Patricia A. Plunkert, "Aluminum," *Minerals Yearbook,* vol. I, 1988 ed. (Washington, DC: U.S. Department of the Interior, Bureau of Mines, 1990).

Figure 3-2—U.S. Aluminum Production and Consumption, 1975-89



NOTE: Secondary production is refined metal and other products recovered from old and new scrap. Bars labeled 75-79 represent averages for the period 1975-79.
SOURCE: *Metal Statistics*, Metallgesellschaft Aktiengesellschaft.

Figure 3-3—NSW Aluminum Production and Consumption, 1975-88



NOTE: Secondary production is refined metal and other products recovered from old and new scrap. Bars labeled 75-79 represent averages for the period 1975-79.
SOURCE: *Metal Statistics*, Metallgesellschaft Aktiengesellschaft.

wood, and Northwest Aluminum) entered U.S. industry during the decade. A seventh (Ormet) was essentially new to the industry also. It was sold to its current owners, Ohio River Associates, in 1986.

PRODUCER PROFILES, 1990

Since the second World War, two major groups of countries have been involved in the production of aluminum, the ''miners' and ''smelters. " Bauxite was mined in tropical developing countries such as Guyana, Guinea, Jamaica, and Suriname. Aluminum was smelted in the electricity-rich developed regions of North America and Europe. Alumina refining, the middle processing step, originally took place in the smelting countries, but is now done in the mining countries also.

A new group of "integrated' producing countries, active in all three sectors of the primary aluminum business, has emerged in the last 20 years. Australia and Brazil are two such producers (see figure 3-4). Australia is the largest NSW bauxite miner and alumina refiner, and ranks third in smelting. Brazil's industry is smaller, ranking third in mining, fifth in refining, and fourth in smelting.

The other major bauxite producers are involved in the processing sector to varying degrees. Guinea, Guyana, and Sierra Leone have little or no refining capacity and export most of their output. Jamaica, Suriname, India, Yugoslavia, and Greece have significant refinery capacity, and export both alumina and bauxite.

Until the ascendancy of Australia and Brazil, the smelting industry was located almost exclusively in North America, Japan, and Europe. The United States has been the largest smelting country since the birth of the industry. Japan was the second largest smelter in the mid- 1970s, but has since closed most of its capacity because of high electricity prices. Canada is now the second largest producer. In Europe, where most nations have some smelting capacity, Norway and West Germany are the industry leaders. Among the older smelting countries, the United States, West Germany, and Canada have the largest refining sectors.

Despite the industry's geographical diversity, a high degree of concentration and vertical integration was attained by the major companies. The Big Six (Alcoa, Alcoa, Kaiser, Reynolds, Pechiney, and Alusuisse) operated as an oligopoly for most of the post World War II period (see box 3-A). Although these companies were principally smelters and fabricators, they owned or controlled most of the world's bauxite production. Over the years, the Big Six have lost some of their influence over the industry, especially in the mining sector, but the individual companies remain important.

The International Bauxite Association (IBA) was established in 1974. Its members are Australia, Ghana, Guinea, Guyana, India, Indonesia, Jamaica,

Table 3-I—Profile of U.S. Primary Aluminum Production industry, 1980 and 1990

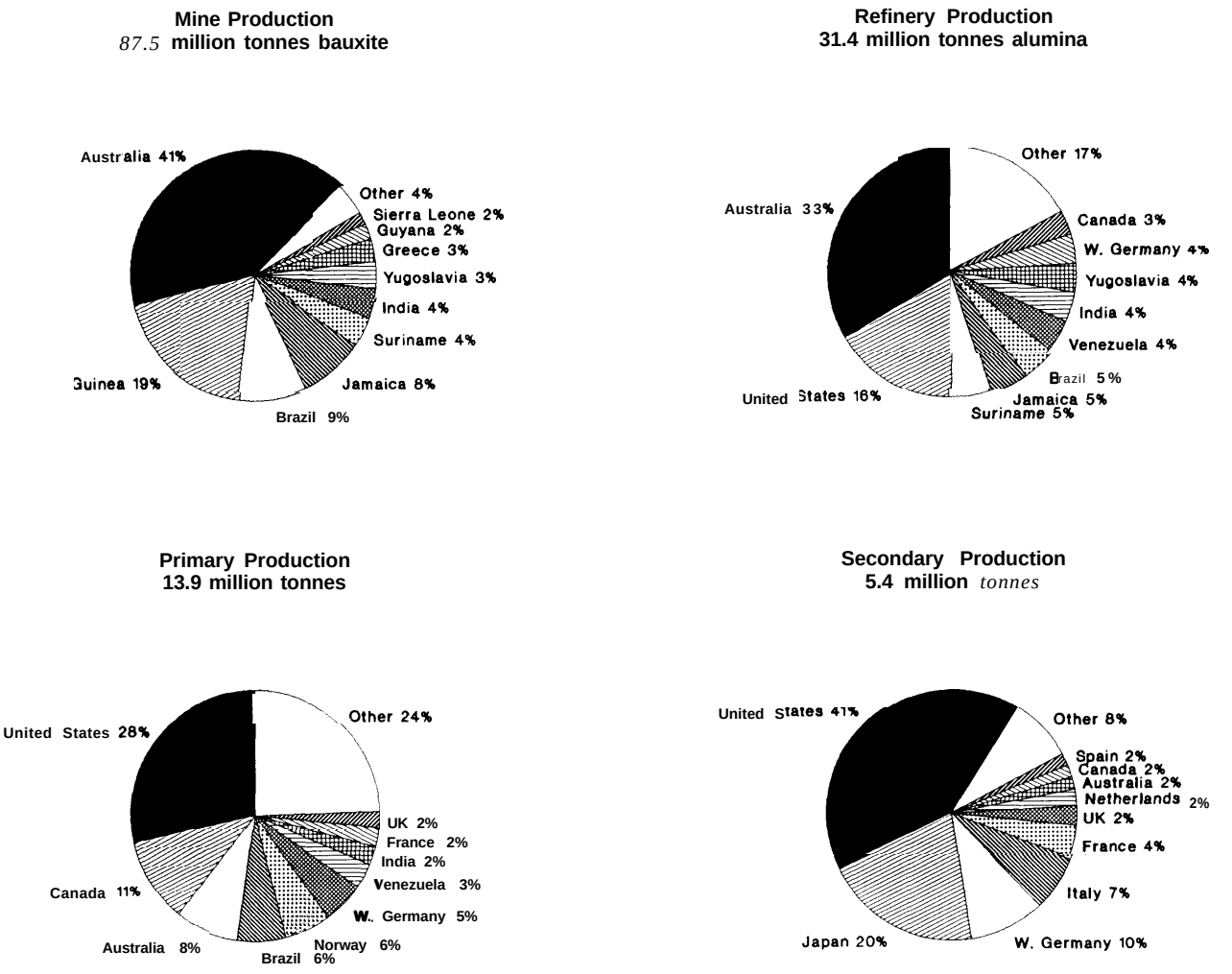
1980	1990	
Alumina refiners:		
Point Comfort, TX.. . . . . Alcoa	Alma	
Bauxite, AR . . . . . Alma	Alcoa	Has produced only specialty alumina (no metal-grade alumina) since 1988
Mobile, AL . . . . . Alcoa	—	Closed 1982; permanent closure 1984
St Croix, Virgin Islands . . . . Martin Marietta	Clarendon[a]	Closed 1985; sold to Clarendon 1989; reopened 1990
Gramercy, LA . . . . . Kaiser	Kaiser[b]	Note 1
Baton Rouge, LA . . . . . Kaiser	—	Closed 1983; permanent closure 1985; specialty alumina plant sold to LaRoche Chemicals 1988
Burnside, LA . . . . . Ormet[c]	Ormet[d]	Closed 1985; reopened 1988; Notes 2,3,4 ote 3/
Corpus Christi, TX . . . . . Reynolds	Reynolds	
Hurricane Creek, AR . . . . . Reynolds	—	Closed 1983; permanent closure 1984
Aluminum smelters:		
Sebree, KY . . . . . Anaconda Aluminum	Alcan	Note 5; sold to Alcan 1985
Rockdale, TX . . . . . Alcoa	Alcoa	Capacity reduced 1986, restored 1987
Evansville, IN . . . . . Alcoa	Alcoa	
Wenatchee, WA . . . . . Alcoa	Alma	
Alcoa, TN . . . . . Alcoa	Alcoa	Capacity reduced 1986, restored 1987
Massena, NY . . . . . Alma	Alcoa	Capacity reduced 1986
Badin, NC . . . . . Alcoa	Alcoa	
Palestine, TX . . . . . Alma	—	Closed 1983; permanent closure 1985; experimental plant
Point Comfort, TX . . . . . Alcoa	—	Closed since 1978; permanent closure 1982
Mount Holly, SC . . . . . Alumax[e]	Alumax-Clarendon[f,g]	Opened 1980; Notes 6&7
Frederick, MD . . . . . Eastalco[e,h]	Alumax-Mitsui[f,i]	Notes 8,6,9
Ferndale, WA . . . . . Intalco[e,h]	Alumax-Mitsui[f,i]	Notes 8,6,9
Goldendale, WA . . . . . Martin Marietta[j]	Columbia Aluminum[k]	Sold to Comalco 1985, to Columbia Aluminum 1987
Columbia Falls, MT . . . . . Anaconda Aluminum	Columbia Falls[l]	Note 5; sold to Columbia Falls 1985
New Johnsonville, TN . . . . Conalco[m]	—	Closed 1986; Note 2
Lake Charles, LA . . . . . Conalco[m]	—	Closed 1981; Note 2; carbon plant sold to Reynolds 1983
Mead, WA . . . . . Kaiser	Kaiser[b]	Note 1
Tacoma, WA . . . . . Kaiser	Kaiser[b]	Note 1
Chalmette, LA . . . . . Kaiser	—	Closed 1983; capacity written off 1986-87; Note 1
New Madrid, MO. . . . . Noranda	Noranda	
The Dalles, OR. . . . . Martin Marietta[j]	Northwest Aluminum[n]	Northwest Al signed lease-purchase agreement 1986
Hannibal, OH . . . . . Ormet[c]	Ormet[d]	Notes 2,3,4
Ravenswood, WV . . . . . Kaiser	Ravenswood[o]	Note 1; sold to Ravenswood 1988
Scottsboro, AL . . . . . Revere Copper& Brass	—	Closed 1982; Note 3
Longview, WA . . . . . Reynolds	Reynolds	
Massena, NY . . . . . Reynolds	Reynolds	
Troutdale, OR . . . . . Reynolds	Reynolds	
Listerhill, AL . . . . . Reynolds	—	Closed 1986
Jones Mills, AR . . . . . Reynolds	—	Closed 1985
Arkadelphia, AR . . . . . Reynolds	—	Closed 1985
San Patricio, TX . . . . . Reynolds	—	Closed 1981; permanent closure 1984
Hawesville, KY . . . . . National-Southwire[p]	Southwire	Note 10
Vancouver, WA . . . . . Alcoa	Vanalco	Sold to Vanalco 1987

NOTES:

[a]Clarendon is a subsidiary of Marc Rich.
[b]Kaiser is a subsidiary of Maxxam.
[c]Ormet was a subsidiary of Conalco (owned by Alusuisse and Phelps Dodge) and Revere Copper and Brass.
[d]Ormet is a subsidiary of Ohio River Associates.
[e]Alumax was a subsidiary of Amax 50%, Mitsui 45% and Nippon Steel 5%.
[f]Alumax is a subsidiary of Amax.
[g]The Mount Holly, SC, smelter is owned by Amax 73% and Clarendon (a subsidiary of Marc Rich) 27%.
[h]Eastalco and Intalco were subsidiaries of Alumax . and Howmet, a subsidiary of Pechiney.
[i]The Ferndale, WA, and Frederick, MD, smelters are owned by Alumax 75%, Mitsui 11%, Toyo Sash 7%, and Yoshida Kogya 7%.
[j]The Dalles, OR, and Goldendale, WA smelters were 87°/0 owned by Martin Marietta.
[k]Columbia Aluminum is 30% employee owned.
[l]Columbia Falls is a subsidiary of Montana Aluminum Investors.
[m]Conalco was a subsidiary of Alusuisse 60% and Phelps Dodge 40%.
[n]The Dalles, OR, smelter is 87% owned by Martin Marietta and operatad by Northwest Aluminum under a lease-purchase agreement.
[o]Ravenswood isa subsidiary of Stanwich Partners.
[p]National-Southwire was a subsidiary of National Steel (later National Intergroup) and Southwire.
[1]Alan Clore acquired control of Kaiser 1986. Maxxam acquired Kaiser 1988.
[2]Alusuisse became the sole owner of Conalco by purchasing the share of Phelps Dodge 1980.
[3]Revere Copper and Brass began operating under Chapter 11 of the bankruptcy code in October 1982.
[4]Ohio River Associates, an investor group, acquired Ormet through a leveraged buyout 1986. Conalco and Revere Copper and Brass received prorated shares of the Hannibal, OH plant output for the first four years of production.
[5]Atlantic Richfield (Arco) acquired Anaconda Aluminum 1982.
[6]Amax became the sole owner of Alumax by purchasing the shares of Mitsui and Nippon Steel 1986.
[7]Clarendon, a subsidiary of the Marc Rich trading company, acquired a 27 percent interest in the Mount Holly, SC smelter 1987.
[8]Alumax became the sole owner of Eastalco and Intalco by purchasing the assets of Howmet, a subsidiary of Pechiney 1983.
[9]A consortium of Mitsui, Toyo Sash, and Yoshida Kogya acquired a 25 percent interest in the Ferndale, WA and Frederick, MD smelters 1988.
[10]Southwire became the sole owner of the Hawesville, KY smelter by purchasing the share of National Intergroup 1990.

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

Figure 3-4—NSW Aluminum Production, Country Profile, 1988



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

Sierra Leone, Suriname, and Yugoslavia. These countries produced about 85 percent of the NSW's bauxite and about half of the alumina in 1988. The goals of the IBA are to promote the orderly and rational development of the bauxite industry, to secure fair and reasonable returns for the exploitation of the bauxite, and to generally safeguard members' interests in relation to the bauxite industry.[7] The interest in establishing the organization came in the early 1970s. Bauxite-producing nations were dissatisfied with the revenues their resources were generating. It was also during this period that bauxite levies and government equity positions in bauxite companies became popular. The final inducement for forming a producer organization came when the Organization of Petroleum Exporting Countries (OPEC) was successful in quadrupling oil prices in 1973.

[7]G.R. Peterson and S.J. Arbelbide, *Aluminum Availability—Market Economy Countries*, IC 8917 (Washington, DC: U.S. Department of the Interior, Bureau of Mines, 1983).

Box 3-A—The Big Six Aluminum Companies

Aluminum was not produced commercially until late in the 19th century, long after most other structural metals had found widespread use. Alcoa (then the Pittsburgh Reduction Co.) controlled the North American aluminum industry from its inception until World War II.

In the mid-1940s, the country's capacity was tripled to meet growing military needs. The U.S. Government, through the Defense Plant Corp., built new aluminum smelters which were then operated by Alcoa and several other companies. Following the war, the smelters were leased and then sold to two of the operators, Kaiser and Reynolds as part of an antitrust action against Alcoa. In 1950, Alcoa was ordered to divest itself of its Canadian affiliate Alcan (then Aluminum Ltd.). Consequently, the North American monopoly held by Alcoa was replaced by the oligopoly resulting from the emergence of Alcan, Kaiser, and Reynolds as major producers.

In Europe, a more oligopolistic aluminum industry developed in the early years. After World War II, government actions consolidated the position of Pechiney and Alusuisse in this market.

Though their market control declined, these "Big Six" companies accounted for about 65 to 85 percent of NSW aluminum production from World War II to the early 1970s. The leaders were able to set prices at cost plus a margin of profits, know as 'producer prices." Prices remained stable, because changes in demand were met with immediate adjustments to inventories and operating rates. In the long run, the major producers kept prices stable by building capacity in anticipation of demand. This "planned excess capacity" enabled the major producers to supply their customers as their demand increased and also provided an added barrier to entry into the industry.[1] The high rate of growth in aluminum consumption and the coordination of capacity expansion among the major producers made this strategy very successful.

During this time, the major producers strove for a high degree of vertical integration. Control of bauxite and alumina resources enabled them to supply their own operations at cost, with profits realized at the latter stages of production. Excess raw materials were selectively sold by the leaders so that they could decide, in effect, who their competition would be. The same factors that strengthened Alcoa's earlier in the century-control of natural resources, high barriers to entry and access to the lowest cost energy—provided the oligopolistic leaders with the competitive edge to control the industry from the 1940s until the 1970s.

In the early 1970s, the aluminum industry changed radically and the competitiveness of the top producers was shaken. Electricity, labor, and capital costs rose sharply and demand slowed. As the profit margins declined, the major producers began to pursue different strategies. LME pricing took effect in the late 1970s. The leaders no longer operated as a cohesive group. Some sought to maintain prices by reducing production, while others built capacity in low cost foreign locations. Both strategies were unsuccessful at maintaining the producers' market power.

Concentration of Primary Aluminum Production (percent of NSW production)

	1955	1965	1970	1972	1981
Alcoa	23.2	17.1	16.3	15.4	13.8
Alcan	24.5	15.6	16.3	15.3	11.9
Reynolds	13.5	13.2	12.8	11.0	9.8
Kaiser	13.3	11.5	9.4	8.8	8.4
Pechiney	6.1	8.4	9.3	8.1	8.0
Alusuisse	4.0	6.8	6.6	5.6	5.7
Big Six	84.5	72.3	70.7	64.2	57.7

SOURCE: J.L. Mardones et al., "The Copper and Aluminum Industries: A Review of Structural Changes," Resources Policy, March 19S5.

[1] Paulo de Sá, "Structural Changes and Price Formation in the Minerals and Metals Industry," *Resources Policy, vol.* 14, December 1988.

United States

The United States mines little metallurgical-grade bauxite, but is the NSW's second largest alumina refiner and largest aluminum smelter. All of the domestic alumina refineries are located near the Gulf Coast (see table 3-l). Smelter capacity is located roughly one-third in the Pacific Northwest, one-third in the Ohio Valley, and the rest in the Carolinas, New York, and Texas.

Nearly all U.S. aluminum production is based on imported raw material. In terms of recoverable aluminum, the imports are about one-half bauxite and one-half alumina The principal sources are Guinea and Jamaica for bauxite and Australia for alumina.[8] The major U.S. aluminum companies own shares of many of their foreign suppliers.[9]

The United States produces about a quarter of the NSW's aluminum metal, but does not make enough to meet its fabricating needs. During 1984-88, the country's net imports averaged 12 percent of its consumption of primary and secondary aluminum. Most of the imported metal comes from Canada. Exports during this period were 17 percent of domestic production.

Three companies (Alcoa, Reynolds, and Kaiser) own about 90 percent of the country's refinery capacity (see figure 3-5). They, along with a fourth firm (Alumax), own about 60 percent of domestic smelter capacity. These companies are also heavily involved in the downstream fabrication sectors of the business. Having both smelting and fabricating capabilities helps the companies manage business risk. Though the various downstream products vary in their exposure to aluminum ingot prices, rising prices generally favor smelters and declining prices favor the fabricated products.[10] The remainder of the primary aluminum industry is comprised of seven domestic firms (Ormet, Southwire, Columbia Aluminum, Columbia Falls, Vanalco, Ravenswood, and Northwest Aluminum) and two Canadian firms (Alcan and Noranda).

Alcoa

Early in the century, Alcoa held a monopoly over the aluminum industry. Though its influence has since diminished greatly, it remains the world's largest aluminum company and the Nation's leading nonferrous metals producer.[11] Its domestic facilities include refineries in Texas and Arkansas, and smelters in Texas, Indiana, Washington, Tennessee, New York, and North Carolina. The six smelters account for about 31 percent of total U.S. capacity, and an estimated 60 percent of the company's worldwide smelting capacity. Alcoa's major foreign interests include bauxite and alumina facilities in Jamaica, Suriname, and Guinea; and smelters in Australia, Brazil, Norway, Suriname, and Mexico.

Alcoa has diversified over the years, but is still principally an aluminum company .12 Aluminum ingots, chemicals, and fabricated products account for about 90 percent of the company's sales. Some of the aluminum is sold as primary metal, but more is sold as packaging materials (e.g., can stock and bottle caps) and sheet, plate, and extrusions for aerospace and industrial applications.

The company's emphasis on the fabricating business has left it with insufficient primary metal capacity to meet all of its needs. Alcoa buys about one-half of the aluminum used in its fabricated products. To further its goals as both a buyer and a seller of aluminum ingot, the company is an active hedger in the commodities futures markets.

Alcoa has a reputation for being among the most innovative of the companies in the nonferrous metals industry. It spends heavily on research and

[8] During 1985-88, bauxite imports came from Guinea (50 percent), Jamaica (23 percent), Australia (11 percent), and Brazil (5 percent). Alumina imports came from Australia (80 percent), Suriname (8 percent), and Jamaica (5 percent). U.S. Bureau of Mines, *Mineral Commodity* Summaries, 1990 ed. (Washington DC: U.S. Department of the Interior, Bureau of Mines, 1990).

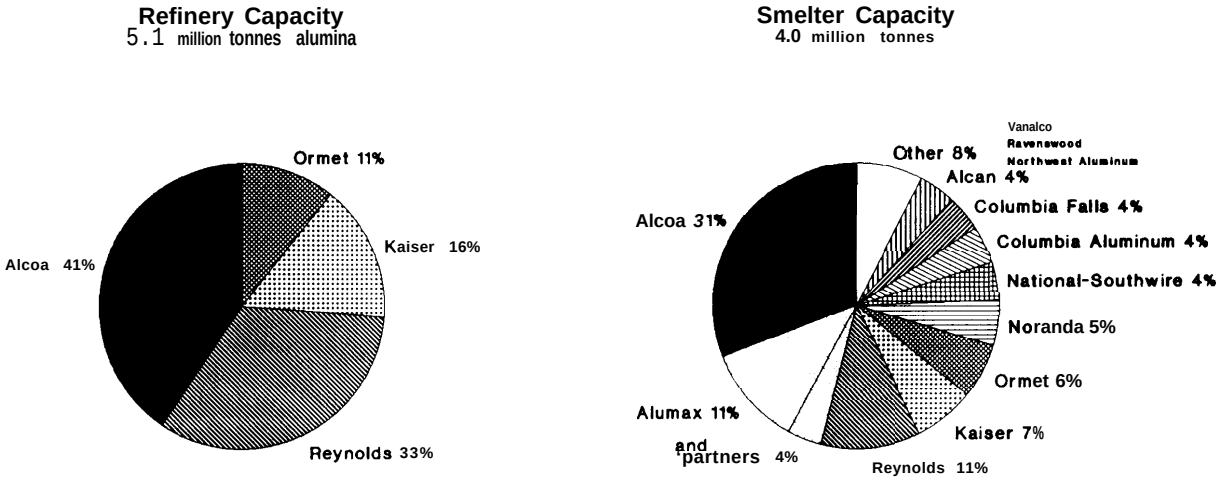
[9] U.S. aluminum companies do not typically own their foreign suppliers outright, but in partnership with other multinational aluminum producers and local governments.

[10] Companies am becoming increasingly aware Of the Opportunity COSt Of aluminum ingot and transferring metal at this cost (the going aluminum price) to their fabricating facilities. Price increases cannot be passed on in the case of low-end fabricated products (e.g., common alloy sheet used in the building, construction and transportation sectors) that have low margins. These products are typically undifferentiated and as such must compete in terms of price. Higher end products (e.g., aerospace plate) do not necessarily compete in terms of price and have large enough margins to allow producers to either pass on price fluctuations or absorb them. These are generally niche markets. Based on reviewer comments by RSI Inc.

[11] Alcoa is the only nonferrous metals company included in the Dow Jones 30 Industrials stock index.

[12] The company's nonaluminum activities are mainly in the area of materials sciences, including electrical, ceramic, plastic, and composite materials, manufacturing equipment, and separations and defense systems.

Figure 3-5--U.S. Aluminum Industry, Company Profile, 1988



NOTE: Alcoa's refinery capacity includes 340,000 mt of capacity that was closed in 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.

Alcoa and its share of affiliates (000s mt)	1986	1987	1988
Sales:	*452*	*493*	*796*
Primary metal			
Fabricated and finished products	1,563	1,720	1,708
Total	2,015	2,213	2,504
Production:			
Primary metal	1,401	1,498	1,814
Recycled cans	200	225	270
Total	1,601	1,723	2,084

development ($120 million to $167 million annually during 1985-88) for both manufacturing technologies and product development.[13]

During the mid-1980s, Alcoa pursued a three-pronged strategy. It sought to withdraw from the primary aluminum business, to develop a higher degree of downstream integration, and to diversify into the production of engineering materials. The goal was to have one-half of its sales come from new nonaluminum businesses by 1995. The company has since slowed its diversification into engineering materials and concentrated its efforts on the aluminum metal and fabrication businesses.[14]

Reynolds

Reynolds, the second largest U.S. aluminum company, has been in production since the 1940s. It operates a refinery in Texas and smelters in Washington, New York, and Oregon. The three domestic smelters account for 11 percent of U.S. capacity. Reynolds' major foreign operations include bauxite mines in Brazil, Jamaica, Guinea, and Australia; refineries in Australia, Jamaica, and West Germany; and smelters in Canada, Ghana, Venezuela, and West Germany. At yearend 1988, over 90 percent of the company's primary capacity was in North America.

Aluminum products accounted for about 85 percent of the company's sales in 1988. Reynolds sells some aluminum ingot, but stresses its fabricating business. The company's emphasis on finished goods, however, is greater than that of its competitors. It is the only aluminum producer that makes cans from its can stock. Reynolds' largest business is its packaging and containers line, which includes aluminum, plastic, and paper consumer products (e.g., aluminum foil, plastic wrap, waxed paper, food containers, and garbage bags). The company also manufactures aircraft and automotive products. The

[13] Alcoa Annual Report, 1988.

[14] Olivier Bomsel and Paulo de Sá, *Diversification: What Direction for Growth To Cope With Price Uncertainty*, Seminar on Mineral Economics and Strategy, Centre d'Economic des Resources Naturelles (CERNA), Ecole Nationale Supérieure des Mines des Paris, June 1989.

Reynolds and its share of affiliates (000s mt)	1986	1987	1988
Aluminum sales:			
Primary metal	111	128	156
Fabricated products	654	733	787
Finished products	331	348	379
Total	1,096	1,208	1,322
Aluminum production:			
Primary metal	654	769	845
Recycled	281	311	369
Total	935	1,080	1,214

5-year plan announced in 1987 calls for expansion of the foreign operations, including a new can plant in Brazil and new wheel plants in Venezuela and Canada.

Since 1986, the company has been investing heavily in precious metals. It has acquired interests in two Australian gold mines (Boddington and Mt. Gibson). In 1988, Reynolds share of the gold from these two mines was 4.4 million grams.

Though Reynolds stresses that its emphasis remains with fabricated and finished products, it is investing in additional aluminum ingot capacity. It is expanding its Baie Comeau smelter in Canada from the present capacity of 280,000 tpy to 400,000 tpy by 1992. Also, Reynolds acquired a 25 percent equity position in the Becancour smelter in Canada in 1987. The smelter is currently being expanded by 50 percent to 360,000 tpy.[15] The company claims that its present sources of bauxite and alumina (including joint ventures and long-term supply contracts) are more than adequate to meet its requirements for the foreseeable future. Reynolds is a net buyer of scrap and ingot.

Capital spending for modernization in the rnid-1980s was primarily to lower basic metals costs (reduced by about 25 percent during 1983-87). The company's emphasis is now on improving fabricating costs and expects to spend about $300 million per year during 1988-93 in this effort. Its research and development budget has been $32 million annually during the mid-1980s. The emphasis is on the development of products, such as the resealable aluminum cans.

Alumax

Amax, through its Alumax subsidiary, is the third largest U.S. aluminum producer. It operates three smelters, located in Washington, South Carolina, and Maryland. The company owns 11 percent of U.S. smelter capacity.[16] It also has a one-quarter share in the Becancour smelter in Canada.

Amax is a century-old minerals company that has been involved in the aluminum industry (mostly as a partial owner of Alumax) for 35 years.[17] Alumax only became a major producer in the 1980s. It expanded by building the Mt. Holly, South Carolina smelter in 1980 and purchasing the U.S. assets of Pechiney (Howmet) in 1983. In 1986, Amax acquired full control of Alumax.

During 1987-88, Amax sold 27 percent of the Mt. Holly smelter to Clarendon Ltd. and one-quarter of its Washington (Intalco) and Maryland (Eastalco) smelters to the Mitsui trading company and two Japanese fabricating companies.[18] Alumax has a 10-year tolling contract with Clarendon Ltd. The agreement covers 50 percent of Mt. Holly's production, but reports are that Clarendon Ltd. has been taking about three-quarters of the smelter's output.[19] Amax has stated that it intends to rebuild its primary metal business and be more involved in the sale of aluminum metal.[20] To this end, the funds from the two equity sales were used to obtain the company's interest in the Becancour facility in 1988. Alumax also has plans to build a 200,000 tpy smelter at Deschamault in Quebec.

Amax produces aluminum, coal, molybdenum, and gold.[21] Aluminum accounted for about two-thirds of the company's sales during 1987-88. Most

[15] Reynolds Annual Report, 1988.

[16] When the shares of the partner companies are included, the Alumax smelters account for 15 percent of domestic capacity.

[17] For most of its history, Amax was principally a base metals producer. It was the world's fifth largest copper producer until it sold its Zambian properties to that government in 1970. It has since left the copper business completely. Amax also once held 60 percent of the world molybdenum market. It is still a major producer, but has lost much of its control over the market.

[18] Clarendon Ltd., owned by trader Marc Rich, is based in Switzerland and markets alumina produced for the Jamaican Government by the Clarendon JV refinery. Clarendon is thought to control 30 percent of world aluminum trade. Paulo de Sá, *From Oligopoly to Competition: The Changing Aluminum Industry,* Centre d'Economic des Resources Naturelles (CERNA), Ecole Nationale Supérieure des Mines des Paris, February 1989.

[19] David Humphreys, ''Aluminum,'' *Mining Journal, Mining Annual Review, 1988.*

[20] Amax *First* Quarter Report, 1989.

[21] Coal, molybdenum, gold, and other metals accounted for 18 percent, 6 percent, 2 percent, and 7 percent of 1987-88 sales, respectively.

Alumax and its share of affliates (000s mt)	1986	1987	1988
Aluminum sales:			
Primary metal	271	349	254
Fabricated and finished products	533	532	501
Total	805	881	755
Aluminum production:			
Primary metal;	582	668	642

of the aluminum is sold as fabricated products. The company is especially strong in the architectural and building products line.

Kaiser

Kaiser, the fourth largest domestic producer, is the smallest of the U.S. majors. The company has been producing aluminum since the 1940s. Its domestic operations include a refinery in Louisiana and two smelters in Washington. The smelters account for 7 percent of U.S. capacity. Kaiser's foreign interests include bauxite mines in Jamaica; alumina refineries in Jamaica and Australia; and smelters in Ghana, the United Kingdom, Australia, and Bahrain.

Kaiser was the target of several corporate takeover attempts during 1985-87. British investor Alan Clore was successful in acquiring the company in 1987. However, he overextended himself in the process and was forced to sell out to Maxxam in 1988. Maxxam has refocused the company's businesses and reduced its debt by restructuring and asset selling. Kaiser is being regrouped around the aluminum metal products business. Since 1984, the company has sold its agricultural, industrial, and specialty chemicals, refractories, international trading, and real estate operations. The company's Ravenswood smelter was sold to the Stanwich Partners in 1988. Further sales, particularly of foreign operations, are expected.[22]

Kaiser fabricates most of the aluminum it produces. In 1987, the company sold 83 percent of its aluminum in the fabricated form. The biggest product groups are can stock and other sheet and plate products. Other lines include rod, bar, wire, forgings, and extrusions.

Kaiser and its share of affiliates (000s mt)	1986	1987	1988
Sales:			
primary metal	75	125	278
fabricated & finished products	688	649	487
total	763	774	765
Production:			
primary metal	578	633	641

Alcan

Alcan is Canada's principal aluminum company, and most of its operations are in that country (see next section). In the United States, it owns the Sebree, Kentucky smelter, which it bought from Atlantic Richfield (Arco) in 1984.

Noranda

Noranda is a diversified minerals producer that is based in Canada. Its principal primary aluminum facility is its New Madrid, Missouri smelter.[23] Noranda's aluminum fabricating plants are all located in the United States. Overall Noranda's aluminum operations contributed 9 percent of the corporation's operating profit (revenues minus costs and depreciation) in 1988.[24]

Other U.S. Producers

Independent firms held 27 percent of U.S. smelter capacity in 1988. National-Southwire ran the smelter at Hawesville, Kentucky. The company, a joint venture of National Intergroup and Southwire, had operated the plant since the late 1950s. In early 1990, Southwire bought out National Intergroup and became sole owner of the smelter. The other six independent companies are all new to the aluminum industry in the 1980s. Ormet, the largest, has a refinery in Louisiana and a smelter in Ohio. Ohio River Associates, an investor group, bought the company from Conalco (Consolidated Aluminum, a subsidiary of Alusuisse) and Revere Copper&Brass in a leveraged buyout in 1986. The purchase agreement calls for the two previous owners to receive part of Ormet product for 4 years. Montana Aluminum Investors purchased the Columbia Falls, Montana smelter from Arco in 1985. Arco had obtained the plant when it purchased Anaconda Aluminum in 1982. Columbia Falls operates the plant, which toll-converts alumina for Hydro Alumi-

[22]David Humphreys, "Aluminum," *Mining Journal, Mining Annual Review, 1989.*

[23]Noranda is also a partial owner of the Friguia mine and refinery in Guinea.

[24]Noranda Annual Report, 1988.

num (Norway) and BHP (Australia). Columbia Aluminum bought the Goldendale, Washington smelter from Commonwealth Aluminum (a subsidiary of Comalco) in 1987. It tolls for Hydro Aluminum and Reynolds, and also produces metal for its own account. Vanalco (owned by Bay Resources) purchased the Vancouver, Washington smelter from Alcoa in 1987. The company produces metal for its own account. Its alumina comes from Alcoa of Australia. Northwest Aluminum (an investor group headed by a former Bonneville Power Authority executive) negotiated a lease-buy arrangement for The Dalles, Oregon smelter with Martin Marietta in 1986. Northwest Aluminum is operating the smelter under a 3- to 5-year lease, and has the option to purchase the plant when the lease expires. The plant is tolling alumina for Clarendon Ltd. Ravenswood (owned by Stanwich Partners) purchased its West Virginia smelter from Kaiser in 1988.

Canada

Canada ranks second in the smelting sector of the NSW aluminum industry. It is a much smaller refining country and has no mine capacity. The industry is based in Quebec, and to a lesser extent, British Columbia. The major foreign sources of alumina are Jamaica and Australia. Canada exports about three-quarters of its primary aluminum. During 1984-88, the United States received 75 percent of Canada's aluminum exports.

Alcan dominates the Canadian aluminum industry. It runs the country's sole alumina refinery, the Vandereuil plant in Jonquiere, Quebec. The facility supplies an estimated 30 percent of Canada's alumina needs. Its bauxite feed is imported from Brazil (mostly MRN's Trombetas mine), Guyana, and Guinea. Alcan has six Canadian smelters, five in Quebec and one in British Columbia, which account for 68 percent of the country's capacity. The largest smelter is the Arvida operation attached to the Vandereuil refinery. Alcan's foreign interests include bauxite mines in Brazil, Guinea, Ghana, Jamaica, India, and Malaysia; refineries in Australia, Brazil, Guinea, Jamaica, India, Ireland, the United Kingdom, and Japan; and smelters in Australia, the United States, Brazil, India, the United Kingdom, Japan, and Spain.

Alcan and its share of affiliates (000s mt)	1986	1987	1988
Shipments:			
Ingot and ingot products	731	787	832
Fabricated products	1,388	1,410	1,446
Total	2,119	2,197	2,278
Production:			
Primary metal *	1,641	1,587	1,619

Alcan, the world's second largest aluminum company, accounted for about 12 percent of NSW primary metal production in 1988.[25] It is a low-cost ingot producer and is known as a fast moving company which buys and sells metal to match the rapidly shifting supply and demand levels worldwide.[24]

The company remains committed to its traditional aluminum business. A new smelter is being built at Laterriere, Quebec to replace several potlines of similar capacity at the Arvida plant that are to be closed for environmental reasons. Facilities are being upgraded to produce higher value ingots. The company's Kemano hydroelectric plant in British Columbia is being expanded to power new smelters that will be built when market conditions are right.

Alcan is also investing in new businesses such as metal matrix composites, aluminum lithium alloys, fiber optics, ceramics, and micro separation technologies. The company has adopted a conservative approach to get into these new businesses. It is building each business step-by-step through joint research projects, small acquisitions, and strategic alliances.

There are two Canadian smelters that are not affiliated with Alcan. Both are in Quebec. The larger, and older, is the Baie Comeau operation owned by Reynolds. It currently accounts for 19 percent of the country's capacity, and is being expanded by 120,000 tpy. The other is the Becancour smelter, equally owned by Reynolds, Pechiney, Alumax, and Albecour (an arm of the Quebec Government). It started production in 1986 and accounts for about 13 percent of Canadian capacity. It is also being expanded by 120,000 tpy.

Several new smelter projects are underway in Canada. Alouette (owned by VAW, Austria Metall, Hoogovens, Albecour, Marubeni, and Kobe Steel)

[25] Alcan owns about 13 percent of the NSW's refinery capacity.

[26] Paulo de Sá, From *Oligopoly to Competition: The Changing Aluminum Industry,* Centre d'Economic des Ressources Naturelles (CERNA), Ecole Nationale Supérieure des Mines des Paris, February 1989.

has announced that it will build a new 278,000 tpy smelter at Sept-Iles, Quebec. Alumax has plans to build a 200,000 tpy smelter at Deschamault in Quebec. When the expansion projects and the new smelters have all been completed (probably in 1992), Canada will overtake the United States as the world's largest aluminum producer.

Australia

Australia is the NSW's largest bauxite miner and alumina refiner, and ranks third in aluminum smelting. It exports an estimated 95 percent of the aluminum content of its bauxite output. Of these exports, roughly one-quarter is in the form of bauxite, 60 percent is in the form of alumina, and the remainder is aluminum metal. Over half of the primary metal exports are bound for Japan, and most of the remainder go to other Asian countries.

Australia's aluminum industry is comprised of five groups of companies, Alcoa of Australia, Comalco, Gove, Worsley, and Alcan Australia. Each is affiliated with the major multinationals.

Alcoa of Australia (partially owned by Alcoa and Western Mining) is Australia's largest bauxite producing concern. It has three large mines (Jarrahdale, Huntley-Del Park, and Willowdale) and three alumina refineries in the Darling Range of Western Australia. It is the world's largest alumina seller. The company also operates two smelters, both near Melbourne in Victoria. It owns the Point Henry facility, and has a 45 percent interest in the Portland plant.[27]

Comalco (partially owned by CRA, an RTZ affiliate) is the country's second largest producer. The company operates two mines (Weipa-Andoom and Mitchell Plateau) in northern Australia. Bauxite from the Weipa-Andoom mine is refined by Queensland Alumina or exported to Japan or Europe. Queensland Alumina (owned by Comalco, Kaiser, Alcan, and Pechiney) runs the Gladstone refinery on the east coast of Queensland. Two smelters, Boyne and Bell Bay, receive their alumina feed from Gladstone. Boyne (owned by Comalco, Kaiser, and a Japanese consortium) is located next to Queensland Alumina. Bell Bay (owned by Comalco) is located in Tasmania.

Gove (partially owned by CSR) is the common thread in the Gove Project mine and refinery and the Tomago smelter. The Gove Project (owned by Gove and Alusuisse) in the Northern Territories is managed by Nabalco. Bauxite from the mine is either refined on site or exported. Tomago (partially owned by Gove, Pechiney, and VAW) runs a smelter in New South Wales.

Australia's other producers are Worsley and Alcan Australia. Worsley (owned by Reynolds, Billiton/Shell Australia, and Kobe Alumina) runs the Mt. Saddleback mine and the Worsley refinery in the Darling Range of Western Australia. Alcan Australia runs the Kurri Kurri smelter in New South Wales.

Brazil

Brazil ranks third in the NSW in bauxite mining and fourth in aluminum smelting. The refining sector is disproportionately small, thus Brazil has net exports of bauxite and aluminum, but net imports of alumina. The bauxite is exported mostly to Canada and Venezuela. During 1984-87, Brazil exported 41 percent of its primary aluminum output, primarily to Japan, Europe, and the United States.

Mineracao Rio do Norte (MRN) is Brazil's largest bauxite mining company. The company's largest holder is the partially government-owned Companhia Vale do Rio Doce (CVRD). Lesser stakes in MRN are held by Alcan, Cia Brasileira de Aluminio (CBA), Billiton, Reynolds, and Norsk Hydro. MRN's mine at Trombetas in the State of Para accounts for about three-quarters of Brazil's bauxite production. Most of the operation's output is exported. Brazil's other mines are run by Alcan Aluminio, CBA, and Alcoa Aluminio (partially owned by Alcoa). Their bauxite is, for the most part, refined and smelted domestically.

Four companies operate both refineries and smelters in Brazil. The largest is Alumar (owned by Alcoa Aluminio and Billiton). Its facilities are located at Sao Luis, Maranhao and currently account for about 28 percent of the country's smelting capacity. The Sao Luis smelter is being expanded from 245,000 tpy to 328,000 tpy. The other refinery/smelter complexes are run by CBA (Sorocaba, Sao Paulo), Alcan Aluminio (Minas Gerais operations), and Alcoa Aluminio (Pocos de Caldas, Minas Gerais).

[27] Alcoa (through Alcoa of Australia) owns 51 percent of the Point Henry smelter, but has access to all of the metal produced.

Two companies, Albras and Valesul, are involved only in the smelting sector. Albras (owned by CVRD and a Japanese consortium) runs a smelter at Belem, Para. A project to double the capacity of the Belem smelter is underway. Albras has been dependent on imported alumina, because finding problems stalled the construction of the nearby Alunorte refinery. The refinery should be in production by the end of 1990. Valesul (owned by CVRD, Billiton, and Reynolds) runs a smelter in Rio de Janeiro.

Jamaica

Jamaica is the fourth largest NSW miner and refiner, but has no smelting capacity. Most of the country's operations are partnerships between the government and foreign fins. The largest bauxite producer is Kaiser Jamaica (owned by the government and Kaiser). Its Water Valley mine has no associated refinery in Jamaica; most of its bauxite is sent to Kaiser's Gramercy, Louisiana plant. Three other companies operate both mines and refineries in Jamaica. Alpart (owned by Kaiser and Hydro Aluminum) has facilities at Nain. Clarendon Alumina (owned by Alcoa and the government) runs the Breadnut Valley mine and the Clarendon refinery. Jamaican (owned by Alcan and the government) has operations at Ewarton and Kirkvine.

Jamaica's alumina production was uneven in the mid- 1980s. The government and the companies disagreed on whether or not to close various facilities. Alumina export levies and sagging alumina markets (especially the closures of U.S. Gulf Coast smelters) were at the center of the disputes. These problems have generally been resolved. Significant expansion projects are being considered by Alcan, Alpart, and Comalco.

Guinea

Guinea, which ranks second in NSW bauxite output, is the world's largest bauxite exporting country. It has little refinery capacity and no smelting capacity.

The Sangaredi-Boke mine is Guinea's largest mine, accounting for about two-thirds of the country's capacity. It is run by Compagnie des Bauxites de Guinea (CBG) which is owned by the government and Halco (a consortium of Alcoa, Alcan, Pechiney, VAW, Comalco, Aluminia SpA, Reynolds, and Billiton). Most of the bauxite is shipped under long-term contracts to refineries in Europe and the United States. The Endasa plant in Spain and Aughinish plant in Ireland are major recipients.[28]

The next largest mine, Debele, is run by the state-owned Offices de Bauxites de Kindia (OBK). The Soviet Union helped finance the mine and takes a large portion of its output under a barter arrangement. The remaining mine, and the sole refinery, are run by Friguia. The company is owned by the government and Frialco (a consortium of Noranda, Pechiney, British Alcan, Alusuisse, and VAW).

India

India is currently a medium-sized bauxite miner and alumina refiner. It will become a comparable aluminum smelter when ongoing expansion projects are completed in the early 1990s. There are four integrated companies producing aluninum in India. Nalco and Bharat are both owned by the government. Indalco is partially owned by Alcan. Hindalco, until recently, was partially owned by Kaiser. A fifth, smaller company, Malco operates a refinery and smelter, but has no mines.

Suriname

Suriname, once the third largest bauxite miner, is a medium-sized bauxite producer with a small amount of refining and smelting capacity. Suralco (owned by Alcoa) and Billiton operate facilities in the country. Suralco runs a mine and a smelter. Suralco and Billiton jointly own another mine and a refinery.

Yugoslavia

Energoinvest (owned by the government) is Yugoslavia's largest aluminum producer. It runs four mines, two refineries, and a smelter. About half of its alumina production is smelted domestically, and half is exported, primarily to the Soviet Union. The government also owns the country's three other smelters.

Greece

Greece exports most of its bauxite. Parnasse, the countrys largest bauxite producer, accounts for over half of the country's output. The company exports about 60 percent of its bauxite primarily to the

[28] *Annual Review of the World Aluminum Industries 1985*, Shearson Lehman Brothers.

Eastern bloc and Europe. Greek Helikon, another bauxite producer, also exports much of its product. Elbaumin (owned by the government) sends its bauxite to the country's only refinery and smelter, run by Aluminium de Grece (partially owned by Pechiney). Hellenic Alumina (ELVA) is constructing an alumina plant at Thisbi. The plant, which is being partially funded by the Soviet Union, is scheduled for completion in 1992. All of the refinery's output will be exported to the Soviet Union.

Guyana

Guyana has three mines and is estimated to produce 60 percent of the world's nonmetallurgical grade bauxite. It exports most of its product. Guyana nationalized its industry in 1971.

Sierra Leone

Sierre Leone Ore and Metals (SIEROMCO), owned by Alusuisse, is the country's the sole producer. It exports all of its bauxite, primarily to Europe.

Venezuela

Venezuela has carved out a niche as an alumina refiner. It imports bauxite and exports alumina. The country currently has ambitious plans to expand its capacity in the smelting sector. The industry is dominated by the state-owned Corporation Venezolana de Guayana (CVG). The company has some stake in all of the country aluminum operations.

Venezuela began bauxite production with the opening of the Bauxiven (owned by CVG and Alusuisse) Los Pijiguaos mine in 1987. The mine is expected to produce 4 million tpy of bauxite at full capacity. At this rate, Venezuela would be the fifth largest bauxite producer.

Inter-alumina (owned by CVG and Alusuisse) runs the country's sole refinery. It is located at Ciudad Guayana next to two smelters. The larger smelter is run by Venalum (owned by CVG and a consortium of six Japanese companies). The other is operated by Alcasa (owned by CVG and Reynolds).

Venezuela is undergoing an aggressive expansion program to take advantage of its vast bauxite resources and its position as the world's lowest cost aluminum producing country. The Interalumina refinery is being enlarged. The Venalum and Alcasa smelters, with a current capacity of 600,000 tpy, are to be expanded to about 860,000 tpy in the early 1990s. Furthermore, seven other CVG-associated companies Alisa, Alamsa, Aluguay, Alusur, Aluyana, Vexxal, and Angostura have construction plans.[29] If all of the plans were realized, Venezuela's capacity would rise to 1.4 million tpy by 1994 (2.0 million tpy by 2000) and the country would be among the top three or four NSW aluminum smelters.[30] However, the construction schedules are far from certain. The government has proposed delaying five of the seven planned smelters, because of financial problems. Only Alisa has arranged the financing necessary to begin construction on its 120,000 tpy facility.

Norway

Norway produces no bauxite or alumina, but is the world's fifth largest aluminum smelter. It exports about 90 percent of its production, primarily to West Germany, the Netherlands, Italy, and the United Kingdom.

Norway's industry is comprised of three fins. Hydro Aluminum (owned by Norsk Hydro) is the largest. It has four smelters and accounts for almost three-quarters of Norway's capacity. Hydro Aluminum has tolling agreements with Columbia Falls and Columbia Aluminum in the United States, and owns a share of Alpart in Jamaica, to enhance its geographical diversification.[31] Norway's other producers are Mosal (owned by Alcoa and Elkem) with two smelters and Soral (owned by Norsk Hydro and Alusuisse) with one smelter.

West Germany

After Norway, the largest of the European producers is West Germany. Its refinery production is handled by three fins, Aluminium Oxide Stade, Alusuisse, and VAW. Aluminium Oxide Stade (owned by Reynolds and VAW accounts for almost

[29]Among CVG's partners in these ventures are Austria Metall and Pechiney for Alamsa, and Alcoa and Sural for Alusur, possibly Alusuisse and Alumax for Aluguay. Alamsa will build its smelter in neighboring Guyana.

[30]"Venezuela Boosts Aluminum Output," *Engineering and Mining Journal,* May 1988. David Humphreys, "Aluminum," *Mining Journal, Mining Annual Review, 1988.*

[31]David Humphreys, "Aluminum," *Mining Journal, Mining Annual Review, 1988.*

60 percent of the country's refinery capacity. The major suppliers of concentrates are Australia, Guinea, and Sierra Leone.

Four films are involved in the smelting sector. VAW owns about half of the capacity and Alusuisse, through two subsidiaries, accounts for a quarter. The others are Hamburg Aluminum (owned by Reynolds, VAW, and the City of Hamburg) and Hoogovens. Imports of alumina come primarily from Australia, Italy, and Guinea.

France

France's sole aluminum producer is Pechiney (owned by the government). The company is the largest aluminum producer in Europe and the fourth largest in the world. It has interests in bauxite mines in France, Guinea, and Greece; refineries in France, Guinea, Greece, and Australia; and smelters in France, Greece, the Netherlands, Australia, and Canada. Pechiney has a 30 percent interest in the 180,000 tpy Alamsa smelter being proposed in Venezuela. It announced in 1988 that it would build a new 210,000 tpy state-of-the-art smelter in Dunkerque, France. It recently purchased American National Can to enhance its fabricating capabilities in the United States.

Switzerland

Switzerland produces little aluminum, but is home to Alusuisse. The company (also called Swiss Aluminum) is the smallest of the majors. It owns major shares of bauxite mines in Australia, Sierra Leone, and Guinea; refineries in Australia and West Germany; and smelters in Norway and West Germany. Minor interests are held in mines and refineries in Venezuela.

In 1987, 69 percent of Alusuisse's sales came from aluminum products and the remainder came from chemicals. The aluminum was sold mostly as fabricated products (64 percent), but also as primary metal (20 percent), and bauxite and alumina (10 percent). The major markets were Europe and, to a lesser extent, North America. Because of the weak European markets of the mid-1980s, the company retreated from raw material production and expanded into fabricated products.

Alusuisse's corporate strategy calls for a partial withdrawal from primary metal to concentrate on specialized, high-value aluminum products and ceramics, composites, and chemicals. The company's primary metal capacity has been pared to less than half of the 800,000 tpy it once was. About 30 to 40 percent of the metal required by the fabricating operations must be brought from outside the corporation. The smelter capacity that remains is relatively high cost. The alumina and fabricated products segments are somewhat healthier.[32]

The Middle East

There are several producers in the Middle East taking advantage of the low-cost energy (based on natural gas) in that region. The current producers are Alba (partially owned by Reynolds) in Bahrain and Dubai Aluminum in the United Arab Emirates. Capacity in the region is currently being expanded considerably. Alba is expanding its smelter from 180,000 tpy to 225,000 tpy in a program to be completed in 1990. The Bahrain Government is considering further expanding the plant to 400,000 tpy. A consortium of Chinese, U. S., and British investors have plans to build a 240,000 tpy smelter in Qatar, UAE to be completed in 1992. Alujain (controlled by Saudi shareholders) has talked of building a 220,000 tpy smelter in Saudi Arabia.[33]

Other Countries

Other producers include: Aluminio Espanol and Endasa in Spain; British Alcan and Anglesey Aluminum in the United Kingdom; Hoogovens in the Netherlands; Aluminia SpA in Italy; Austria Metall and Salzburger (Alusuisse) in Austria; Grange Aluminum in Sweden; and Aughinish (owned by Alcan and Billiton) in Ireland.

[32]Paulo de Sá, *From Oligopoly to Competition: The Changing Aluminum Industry,* Centre d'Economie des Resources Naturelles (CERNA), Ecole Nationale Supérieure des Mines des Paris, February 1989.

[33]David Humphreys, "Aluminum," *Mining Journal, Mining Annual Review, 1989.*

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.[1] Lead's use as a gasoline additive declined greatly in the last two decades because of environmental regulations.[2] 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 ($PbCO_3$) and anglesite ($pbSO_4$). Commercial ores contain 4 to 12 percent lead. Galena often contains silver/gold and is associated with sphalerite (ZnS), pyrite (FeS_2), and chalcopyrite ($CuFeS_2$). 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.[4] 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.[5] The decopperized bullion is then sent to the refinery.

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

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

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

[3] 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).

[4] 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.

[5] A second dressing is performed if tin removal is necessary.

[6] 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

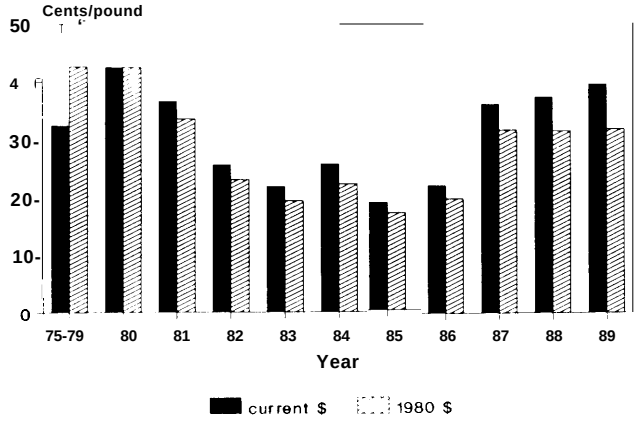
The U.S. lead market started the 1980s on a mixed note (see figures 4-1 and 4-2). In 1980, lead prices (averaging $0.43/lb) were high compared with the late 1970s. Primary and secondary lead production (550,000 and 600,000 tonnes respectively) though were roughly equivalent to late- 1970s levels.

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 refried 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.[7] U.S. lead consumption held fairly steady at 1.1 million tonnes during 1980-87. It then increased slightly to 1.2 million tomes 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 refried production were equal or slightly

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 forthe 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.

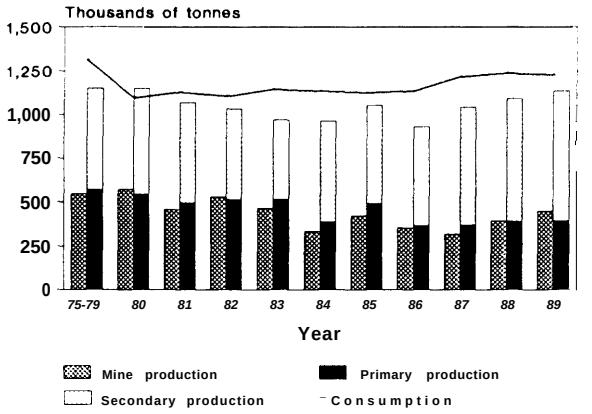
The openings, closings, and ownership changes that occurred in the U.S. primary lead industry during the 1980s are profiled in table 4-1. Two new lead mines (West Fork and Casteel) and two lead-producing precious metals mines (Greens Creek and Montana Tunnels) opened during the decade. The Butte Hill 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.[8] 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

[7]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).

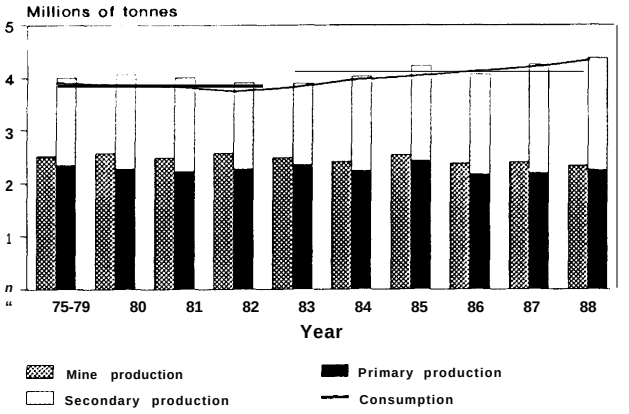
[8]By Convention the elements in multimineral ores mines are listed in order of their descending value (based on price and abundance) in the ores.

Figure 4-2—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.

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.

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 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.[9] 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

[9]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	
Major mines:			
Lead mines:			
West Fork, MO	—	Asarco	Opened 1985
Sweetwater (Milliken), MO	Ozark Lead[a]	Asarco	Closed 1983; sold to Asarco 1986; reopened 1987
Magmont, MO	Cominco-Dresser[b]	Cominco-Dresser[b]	
Buick, MO	Amax-Homestake[c]	Doe Run[d]	Amax share sold to Homestake 1986; Note 1
Fletcher, MO	St. Joe	Doe Run[d]	Notes 2&1
Viburnum #29, MO	St. Joe	Doe Run[d]	Notes 2&1
Casteel (Viburnum #35), MO	—	Doe Run[d]	Opened 1984; owned by Fluor (St. Joe); Note 1
Viburnum #28, MO	St. Joe	Doe Run[d]	Notes 2&1
Brushy Creek, MO	St. Joe	—	Closed 1984; Notes 2&1
Indian Creek, MO	St. Joe	—	Closed 1982; Notes 2&1
Mixed lead-zinc mines:			
Leadville, CO	Asarco-Newmon[e]	Asarco-Newmon[e]	
Bunker Hill, ID	Bunker Hill[f]	Bunker Hill Mining	Closed 1981; Note 3; 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[f,h]	Star-Phoenix Mining	Closed 1982; Star-Phoenix signed 10 year lease-purchase agreement 1989; reopened 1990
Precious metals mines:			
Greens Creek, AK		Greens Creek[i]	Opened 1989; Note 4
Lucky Friday, ID	Hecla	Hecla	
Montana Tunnels, MT	—	Montana Tunnels[j]	Opened 1987; Note 5
Sunnyside, CO	Standard Metals	Washington Mining[k]	Sold to Echo Bay 1985; Note 6
Smelters:			
Glover, MO	Asarco	Asarco	
East Helena, MT	Asarco	Asarco	
El Paso, TX	Asarco	—	Closed 1985
Kellogg, ID	Bunker Hill[f]	.	Closed 1981 (indefinite), 1985 (permanent)
Herculaneum, MO	St. Joe	Doe Run[d]	Notes 2&1
Boss, MO	Amax-Homestake[c]	Doe Run[d]	Amax share sold to Homestake 1986; Notes 1&7
Refineries:			
Glover, MO	Asarco	Asarco	
Omaha, NB	Asarco	Asarco	
Kellogg, ID	Bunker Hill[f]	—	Closed 1981
Herculaneum, MO	St. Joe	Doe Run[d]	Notes 2&1
Boss, MO	Amax-Homestake[c]	Doe Run[d]	Amax share sold to Homestake 1986; Note 1&7

NOTES:

[a] Ozark Lead was a subsidiary of Kennecott, a subsidiary of Standard Oil (SOHIO), a majority-owned subsidiary of British Petroleum.

[b] Cominco and Dresser Industries each own 50% of the Magmont mine. Cominco is the operator.

[c] Amax and Homestake each owned 50 percent of the Buick mine and the Boss smelter/refinery.

[d] Doe Run is a subsidiary of Fluor.

[e] Asarco and Newmont each own 50 percent of the Leadville mine. Asarco is the operator.

[f] Bunker Hill was a subsidiary of Gulf Resources and Chemical Corp.

[g] Cominco-Alaska developed and operates the Red Dog mine. NANA owns the mineral rights.

[h] The Star Morning Unit was owned 70% by Bunker Hill and 30% by Hecla. It was operated by Hecla.

[i] Greens Creek mine is a joint venture of RTZ, Hecla, Exalas Resources Corp. (a subsidiary of Mitsubishi), and CSX Oil & Gas Corp.

[j] Montana Tunnels is a subsidiary of Pegasus Gold.

[k] 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.

[1] 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.

[2] St. Joe acquired by Fluor 1981.

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

[4] Exploration and development led by Noranda 1981-86, British petroleum 1986-1 989; Hecla became a minority partner 1987; RTZ became majority holder 1989.

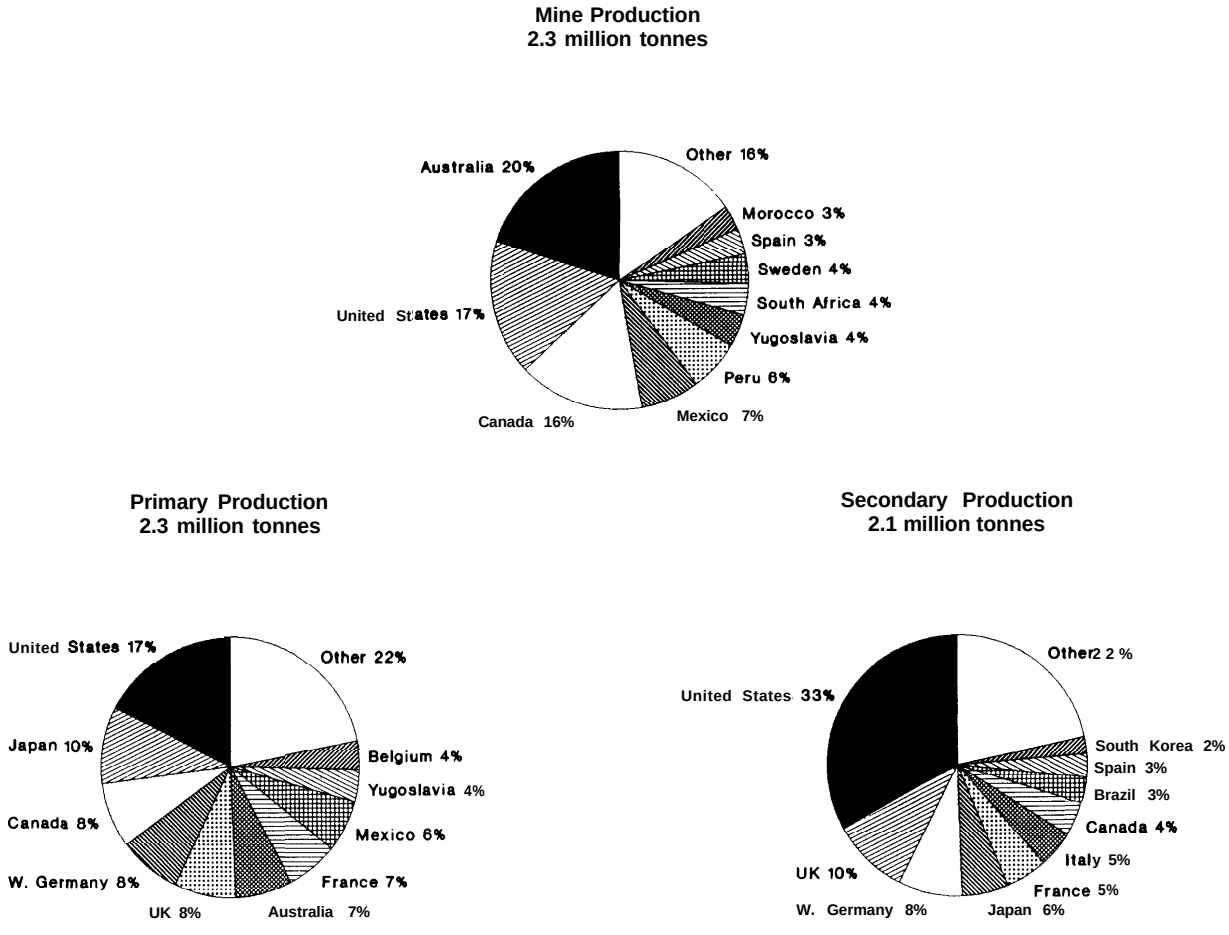
[5] Owned by U.S. Minerals Exploration (USMX); explored by Placer Development 1981-82, Centennial Minerals 1983-85; Centennial Minerals acquired by Pegasus Gold 1985; USMX share sold to Pegasus Gold 1987.

[6] 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%.

[7] 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



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).[10]

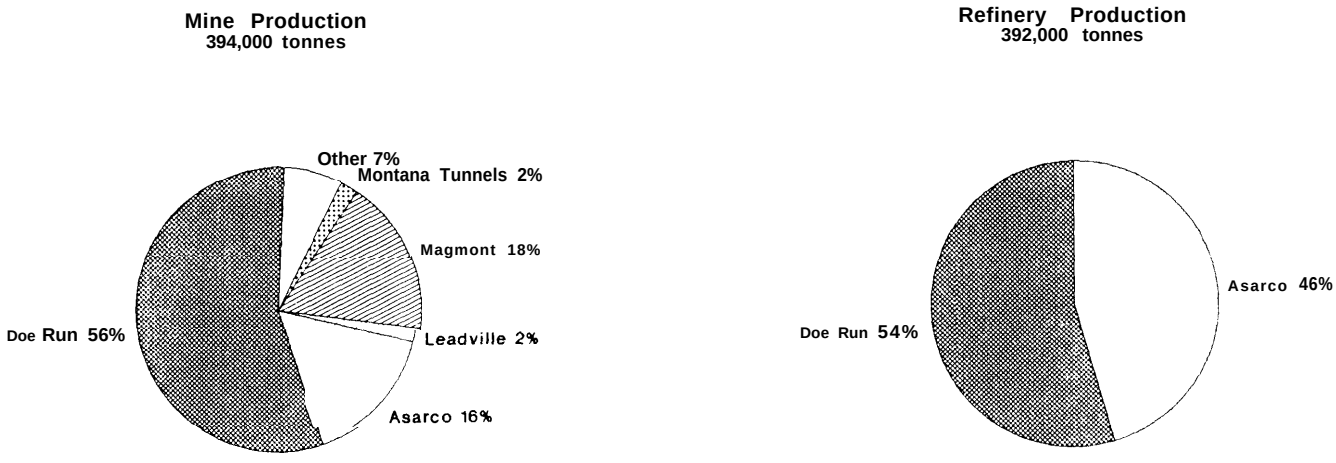
All U.S. lead mines are located in southeastern Missouri's Viburnum Trend, which was discovered and developed in the late- 1960s. These facilities are considered low-cost and competitive in the world market. Their ores are easy to process, because they are relatively homogeneous (containing few byproducts) and mineralogically simple. Furthermore, the deposits are large and amenable to highly mechanized excavation.[11] 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.

[10]U.S. Department of the Interior, Bureau of Mines, *Mineral Commodity Summaries,* 1990 ed. (Washington, DC:1990).

[11]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.[12] 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.[13] 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.[14] Lead accounts for nearly all of Doe Run's sales, but only a small part of those of Fluor.[15] 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.[16]

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.[17] 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.[18]

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

[12] The BOSS smelter is currently being outfitted to process scrap lead.

[13] The St. Joe operations included five mines, three mills, and the Herculaneum smelter/refinery. Homestake contributed the Buick mine and mill and the Boss smelter/refinery.

[14] James H. Jolly, "MineralIndustry Surveys," *Zinc Industry Monthly* (Washington, DC: U.S. Department of the Interior, Bureau of Mines, March 1990).

[15] In 1988, Doe Run accounted for 2.4 percent of Fluor's revenues. Fluor Annual Report, 1988.

[16] This figure includes the entire production of the Leadville mine.

[17] Not including Asarco's nonconsolidated subsidiaries (MIM, Medimsa, and SPCC).

[18] Asarco Annual Report, 1988.

Alaska, which is scheduled to begin production in 1990.[19] This mine has estimated ore reserves of 77 million tomes 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 .20

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, Exalas 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 MINI, a large Australia-based producer of nonferrous metals and coal,[21] 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.[22] 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 .23

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[19]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.

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

[21]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.

[22]Canada produces nearly all of its lead and about half of its zinc from mixed ores.

[23]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.[24] 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. Fare'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.[25]

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 countrys lead and zinc processing capacity, except for one lead bullion smelter (MIM). In terms of refried metal, Pasminco accounts for an estimated 10 percent of NSW zinc production and 7 percent of lead output.[26]

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

[24]Noranda's aluminum smelting facilities are included in its manufacturing sector.

[25]Trelleborg also owns 50 percent of Boliden, a Sweden-based nonferrous metals producer.

[26]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 Kimerly, 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.[27] 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 Monterey, 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

[27] 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 Metallhutten 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 Penarroya (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, Pasde Calais. The facility is somewhat rat-e in that it produces nearly twice as much lead as zinc. The other two-thirds of the countrys refined zinc production comes from Vieille Montagne's plants at Auby.

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.[28]

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).

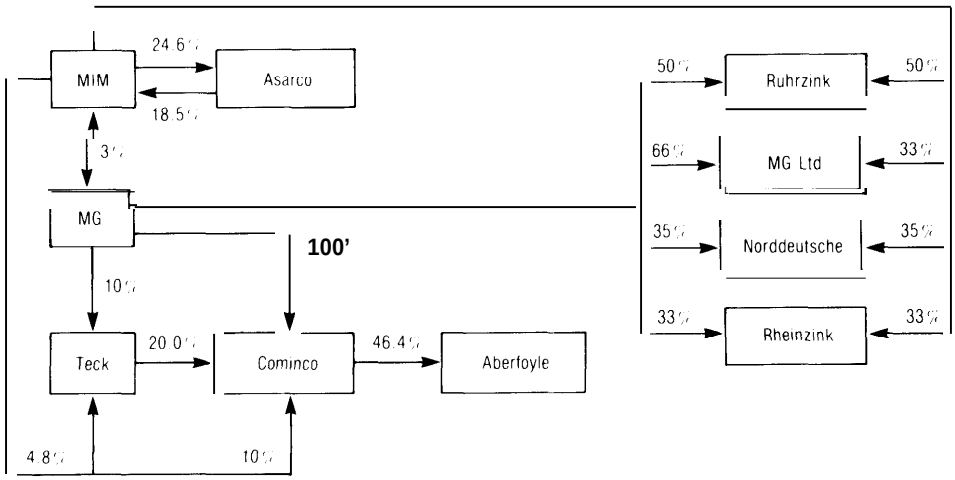
Recent Producer Mergers and Alliances

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.[29]

[28]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).

[29]Paulo de Sá, "Structural Changes and Price Formation in the Minerals and Metals Industry," *Resources Policy, vol. 14, No. 4,* December 1988, pp. 25'7-273.

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.

Chapter 5
Zinc Industry

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 typically 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.

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

WarlH.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).

[3] Zinc 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.

[4] The 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

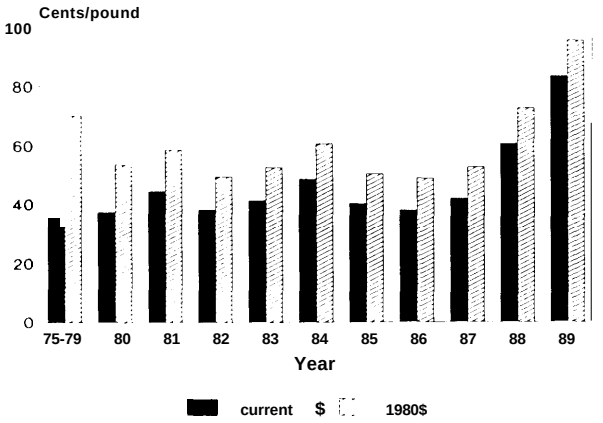
The U.S. zinc market started the 1980s on a mixed note (see figures 5-1 and 5-2). Prices (averaging $0.37/lb) in 1980 were slightly higher than those of the late 1970s. In 1980, domestic mine production (349,000 tonnes) was higher than it had been in the two previous years, but below what it had been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

Figure 5-l—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.

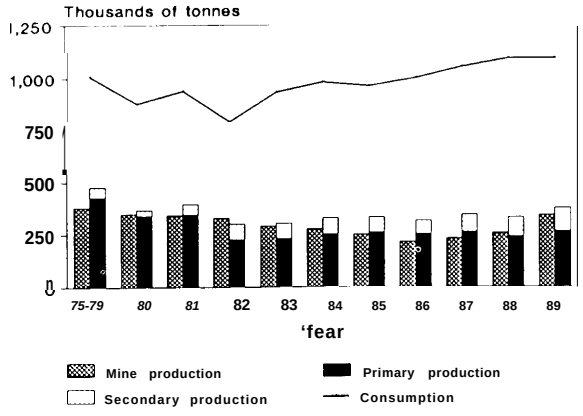
In the nonsocialist world, zinc output and use rose fairly steadily during the decade (see figure 5-3). NSW production and consumption in 1988 were both around 5.2 million tonnes, which represented a 17 percent increase over the 1980 levels.

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 (Pierrepont 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

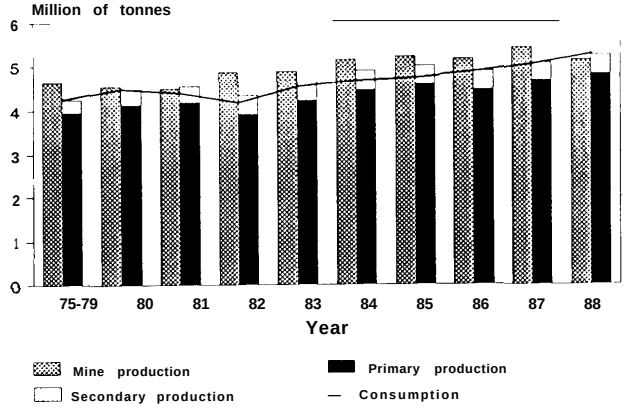
[5]These figures represent the slab zinc recovered from both new and old scrap. Old scrap comes from discarded products, new scrap is waste from fabricating and other manufacturing processes. In 1988,342,000 tonnes of secondary zinc were *recovered from* old scrap (97,000 tomes) and new scrap (245,000 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 5-2--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.

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.

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.

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

[6]In 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.

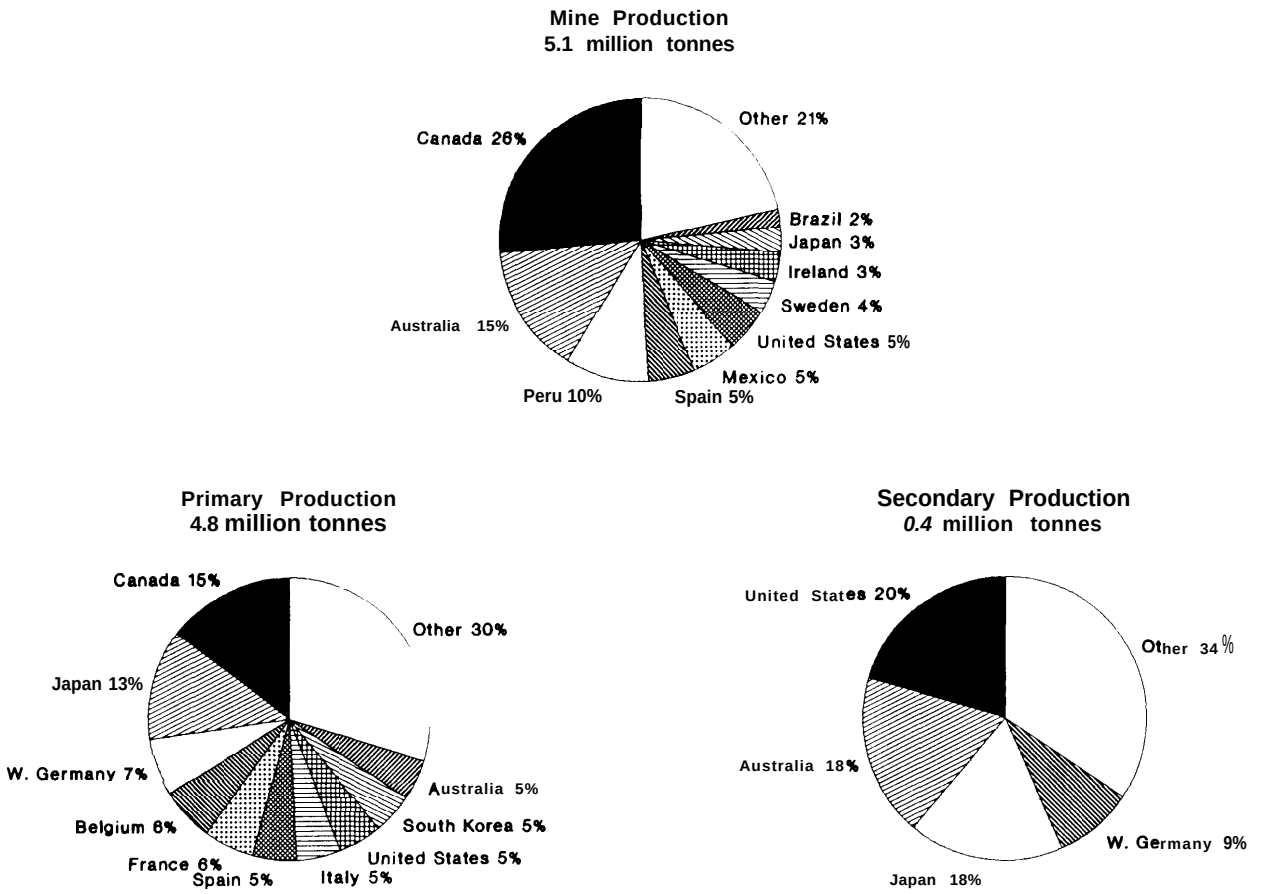
Table 5-l—Profile of U.S. Primary Zinc Production Industry, 1980 and 1990

	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[c]	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[f,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 Minierea[a,b]	Jersey Miniere[c]	Note1; 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

[a] New Jersey Zinc was a subsidiary of Gulf and Western Industries *Inc.*
[b] J„S„ Miniere was a subsidiary of New Jersey Zinc and Union Miniere.
[c] Jersey Miniere is a subsidiary of Union Zinc. Union Zinc is a subsidiary of AceC-Union Miniere.
[d] Zinc Corp. of America (ZCA) is a subsidiary of Horsehead Industries.
[e] Asarco and Newmont each own 50 percent of the Leadville mine. Asarco is the operator.
[f] Bunker Hill was a subsidiary of Gulf Resources and Chemical Corp.
[g] Cominco-Alaska developed and operates the Red Dog mine. NANA owns the mineral rights.
[h] The Star Morning Unit was owned 70% by Bunker Hill and 30% by Hecla. It was operated by Hecla.
[i] Cominco and Dresser Industries each own 50 percent of the Magmont mine. Cominco is the operator.
[j] Amax and Homestake each owned 50 percent of the Buick mine.
[k] Doe Run is a subsidiary of Fluor.
[l] Greens Creek mine is a joint venture of RTZ, Hecla, Exalas Resources Corp. (a subsidiary of Mitsubishi), and CSX Oil & Gas Corp.
[m] Montana Tunnels is a subsidiary of Pegasus Gold.
[n] 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.
I New Jersey Zinc share of Jersey Miniere sold to Union Miniere 1984.
2 St. Joe acquired by Fluor 1981.
3 Zinc 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.
4 Sold t. Horsehead Industries investment group and operated as New Jersey Zinc Co. Inc. (NJZI) 1981.
5 Bunker Hill, ID mine was sold to Bunker Hill Ltd. partnership 1982. Bunker Hill Mining created in public spinoff 1988.
6 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.
7 Exploration and development led by Noranda 1981-86, British Petroleum 1986-1 989; Hecla became a minority partner 1987; RTZ became majority holder 1988.
8 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 Gokt 1987.
9 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% ownad 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/..

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

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

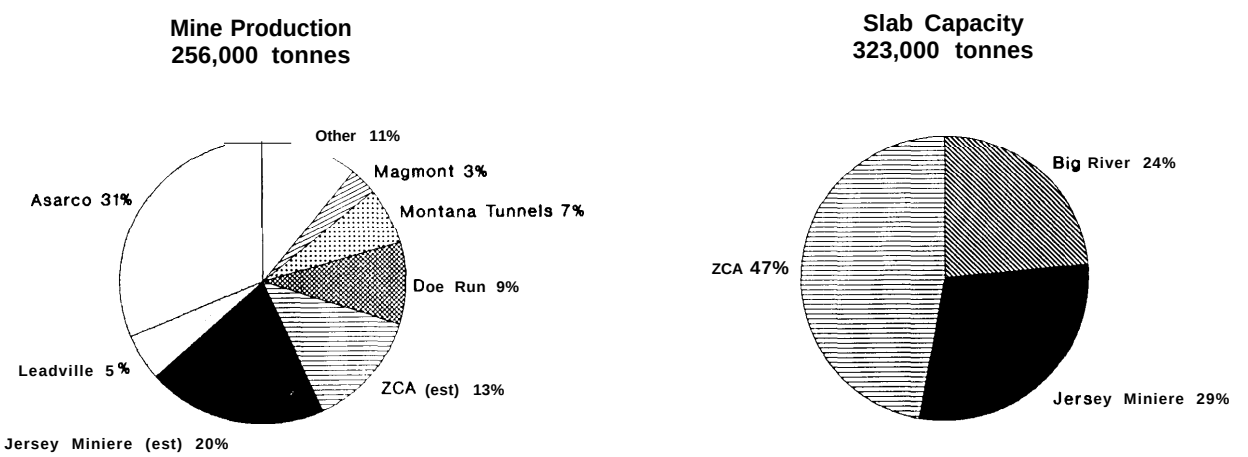
Jersey Miniere is the second largest domestic zinc producer. The company accounted for an estimated 20 percent of U.S. mine production and 29 percent of refinery capacity in 1988. Jersey Miniere's operation is fully integrated. It has a mine and a smelter/refinery in central Tennessee. In addition, its parent Union Zinc, purchased The Zinc Mine Works in Jefferson City, Tennessee from USX in 1989. With this additonal 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

[7]This figure includes entire production of the Leadville mine.

[8]U.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 indudes that of the USX mine purchased in 19S9. 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 tomes of zinc in concentrates, Red Dog will be the world's largest zinc mine. It will nearly double U.S. zinc mine

[9]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.

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.

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

[11] 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.

Appendix A

Historical Rankings of Nonsocialist Copper, Aluminum, Lead, and Zinc Producing Countries

Table A-1- Largest NSW Copper-Produc ng Countries Mine and Meta' Production (thousand metric tonnes contained copper).

Rank	950		1960		1970		1980		1988	
Mine production										
1	United States	825	United States	980	United States	1,560	United States	1,181	Chi e	1,451
2	Chile	363	Zambia	576	Chile	692	Chile	1,106	United States	1,420
3	Zambia	298	Chile	532	Zambia	684	Canada	716	Canada	757
4	Canada	240	Canada	399	Canada	610	Zambia	596	Zambia	480
5	Za re	176	Zaire	302	Za re	387	Zaire	460	Zaire	467
6	Mexico	62	Peru	184	Peru	220	Peru	367	Peru	298
7	Yugoslavia	43	Australia	111	Philippines	160	Philippines	305	Mexico	274
8	Japan	39	Japan	89	Australia	158	Australia	244	Australia	238
9	South Africa	34	Mexico	60	South Africa	149	South Africa	212	Philippines	218
10	Peru	30	South Africa	48	Japan	120	Mexico	175	PNG	214
	NSW	2,287	NSW	3,617	NSW	5,174	NSW	6,066	NSW	6,702
	East	238	East	625	East	1,228	East	1,671	East	2,089
	World	2.525	World	4,242	World	6,403	World	7,737	World	8,791
Metal product or (refined a from pr mary scurces and old and new scrap)										
1	Un ted States	1,344	Unitec States	1,643	United States	2,035	United States	1,686	United States	1,859
2	Chile	300	Zambia	403	Japan	705	Japan	1,014	Chile	1,013
3	Canada	216	Canada	378	Zambia	581	Chi e	811	Japan	955
4	W. Germany	198	W. Germany	309	Canada	493	Zambia	607	Canada	529
5	UK	193	Japan	248	Chile	465	Canada	505	Zambia	445
6	Belgium	137	Chile	226	W. Germany	406	W. Germany	374	W. Germany	426
7	Zaire	97	UK	213	Belgium	338	Belgium	289	Belgium	354
8	Japar	85	Be gium	200	UK	206	Zaire	279	Zaire	283
9	Zambia	79	Zaire	145	Zaire	190	Peru	225	Australia	223
10	Austral a	28	Australia	84	Australia	146	Austra ia	182	Brazil	186
	NSW	498)	NSW (664)	4,198	NSW (1,153)	6,172	NSW (,256	7,080	NSW 1,456	8,041
	East	327	East	800	East	1,419	East	2,217	East	2,523
	Worla	3,187	Worla	4,998	World	7,592	World	9,297	World	10,564

NOTE: NSW secondary production from old and new scrap shown in parentheses.
SOURCE: Metal Statistics (various issues), Metallgesellschaft Aktiengesellschaft.

Table A-2--Largest NSW Aluminum-Producing Countries, Mine and Metal Production (thousand metric tonnes gross weight):

Rank	1950		*1960*		1970		1980		1988	
Mine production:										
1	Suriname	2,045	Jamaica	5,837	Jamaica	12,010	Australia	*27,179*	Australia	36,192
2	Guyana	1,668	Suriname	3,455	Australia	9,256	Guinea	*13,911*	Guinea	16,834
3	United States	1,356	Guyana	2,511	Suriname	6,022	Jamaica	*11,978*	Brazil	7,728
4	France	808	France	2,067	Guyana	4,417	Suriname	*4,903*	Jamaica	7,408
5	Indonesia	531	United States	2,030	France	3,051	Brazil	*4,152*	Suriname	3,434
6	Yugoslavia	206	Guinea	1,378	Guinea	2,490	Yugoslavia	*3,138*	India	3,415
7	Italy	153	Yugoslavia	1,025	Greece	2,292	Guyana	*3,052*	Yugoslavia	3,034
8	**Ghana**	117	Greece	884	United States	2,115	Greece	*3,012*	Greece	2,533
9	**Greece**	77	Malaysia	749	Yugoslavia	2,099	France	*1,892*	Guyana	1,774
10	**India**	65	Dominican Rep	689	India	1,374	India	*1,785*	Sierra Leone	1,379
	NSW	7,085	NSW	22,492	NSW	50,812	NSW	81,244	NSW	87,479
	East	1,333	East	5,128	East	9,898	East	11,500	East	12,806
	World	8,418	World	27,620	World	60,710	World	92.744	World	100,285
Metal production: (refined metal from primary sources)										
1	United States	652	United States	1,828	United States	3,607	United States	4,654	United States	3,944
2	Canada	360	Canada	691	Canada	963	Japan	1,092	Canada	1,535
3	France	61	France	235	**Japan**	728	Canada	1,068	Australia	1,141
4	Norway	45	Norway	171	**Norway**	522	U. Germany	731	Brazil	874
5	Italy	37	W. Germany	169	**France**	381	Norway	662	Norway	827
6	UK	30	Japan	133	**W. Germany**	309	France	432	W. Germany	744
7	W. Germany	28	Italy	84	**Australia**	206	Spain	387	Venezuela	443
8	Japan	25	Austria	68	**India**	161	UK	374	India	335
9	Switzerland	19	Cameroon	44	**Italy**	147	Venezuela	328	France	328
10	Austria	18	Switzerland	39	**Spain**	120	Australia	304	UK	300
	NSW (430)	1,288	NSW (856)	3,618	NSW (2,183)	8,056	NSW (3,868)	12,768	NSW [5,397)	13,852
	East	219	East	911	East	2,246	East	3,286	East	3,628
	World	1,507	World	4,528	World	10,302	World	16,053	World	17,480

NOTE: NSW secondary production from old and new scrap shown in parentheses.
SOURCE: Metal Statistics (various issues), Metal lgesellschaft Aktiengesellschaft.

Table A-3--Largest NSW Lead-Producing Countries Mine and Metal Production (thousand metric tonnes contained lead).

Rank	1950		1960		1970		1980		1988	
Mine production:										
1	United States	391	Australia	313	United States	519	United States	573	Australia	466
2	Mexico	238	United States	224	Australia	457	Australia	398	United States	394
3	Australia	223	Mexico	191	Canada	395	Canada	297	Canada	367
4	Canada	150	Canada	187	Mexico	177	Peru	189	Mexico	171
5	Yugoslavia	86	Peru	131	Peru	157	Mexico	152	Peru	149
6	Peru	62	Morocco	95	Yugoslavia	127	Yugoslavia	122	Yugoslavia	96
7	Morocco	48	Yugoslavia	91	Sweden	78	Morocco	116	South Africa	91
8	W. Germany	47	Spain	73	Morocco	76	Spain	89	Sweden	85
9	Spain	40	Namibia	65	Spain	73	South Africa	86	Spain	75
10	Italy	39	Sweden	55	Namibia	71	Sweden	72	Morocco	70
	NSW	1,525	NSW	1,787	NSW	2,609	NSW	2,564	NSW	[illegible],324
	East	160	East	589	East	854	East	1,025	East	[illegible],097
	World	1,686	World	2,376	World	3.463	World	3,589	World	[illegible],421
Metal production: refined metal from primary sources and old and new scrap)										
1	United States	472	United States	481	United States	730	United States	1,151	United States	1,091
2	Mexico	221	Australia	209	W. Germany	305	W. Germany	350	UK	374
3	Australia	200	W. Germany	207	UK	287	UK	325	W. Germany	345
4	Canada	154	Mexico	167	Japan	209	Japan	305	Japan	340
5	W. Germany	142	UK	148	Australia	208	Canada	235	Canada	268
6	UK	74	Canada	144	Canada	186	Australia	234	France	256
7	Belgium	60	France	110	Mexico	180	France	219	Australia	180
8	Yugoslavia	57	Belgium	93	France	170	Mexico	160	Mexico	179
9	France	51	Yugoslavia	89	Belgium	106	Italy	134	Italy	168
10	[illegible]pain	41	Japan	74	Yugoslavia	97	Spain	121	Yugoslavia	131
	NSW (255	1,678	NSW 40)	2,141	NSW (460)	3,047	NSW (1,788	4,076	NSW 2,113	4,366
	East	172	East	576	East	943	East	1,329	East	1,436
	World	1,850	World	2,717	World	3,990	World	5,405	World	5,802

NOTE: NSW secondary production from old and new scrap shown in parentheses.
SOURCE: Metal Statistics (various issues), Metallgesellschaft Aktiengesellschaft.

Table A-4--Largest NSW Zinc-Producing Countries, Mine and Metal Production (thousand metric tonnes contained zinc).

Rank	1950		1960		1970		1980		1988	
Mine production:										
1	United States	566	United States	395	Canada	1,253	Canada	1,059	Canada	1,347
2	Canada	284	Canada	369	Australia	487	Australia	495	Australia	759
3	Mexico	224	Australia	323	United States	485	Peru	468	Peru	485
4	Australia	201	Mexico	271	Peru	299	United States	349	Spain	277
5	W, Germany	98	Peru	157	Japan	280	Mexico	243	Mexico	261
6	Peru	88	Japan	157	Mexico	266	Japan	238	United States	256
7	Italy	87	Italy	130	W, Germany	161	Ireland	229	Sweden	193
8	Zaire	77	W. Germany	115	Italy	111	Spain	179	Ireland	173
9	Spain	64	Zaire	109	Zaire	103	Sweden	167	Japan	147
10	Japan	52	Spain	86	Yugoslavia	101	W. Germany	121	Brazil	103
	NSW	1,950	NSW	2,595	NSW	4,305	NSW	4,536	NSW	5,098
	East	260	East	756	East	1,257	East	1,656	East	2,010
	World	2,210	World	3,351	World	5,561	World	6,192	World	7,108
Metal production: (refined metal from primary sources and old and new scrap)										
	United States	826	United States	787	United States	866	Japan	735	Canada	703
2	Canada	185	Belgium	248	Japan	681	Canada	592	Japan	678
3	Belgium	174	Canada	237	Canada	418	United States	370	W. Germany	352
4	W. Germany	136	W. Germany	192	W. Germany	301	W. Germany	365	United States	330
5	Australia	84	Japan	187	Australia	256	Australia	301	Australia	303
6	UK	71	France	149	Belgium	232	France	253	Belgium	298
7	France	68	Australia	119	France	224	Belgium	248	France	274
8	Mexico	49	Italy	85	UK	147	Italy	207	Spain	245
9	Japan	49	UK	76	Italy	142	Netherlands	170	Italy	242
10	Norway	43	Zaire	53	Spain	88	Spain	152	South Korea	223
	NSW (160)	1,810	NSW (149)	2,438	NSW (267)	3,955	NSU (349)	4,472	NSW (434)	5,223
	East	250	East	713	East	1,263	East	1,700	East	2,048
	World	2,060	World	3,151	World	5,218	World	6,172	World	7,271

NOTE: NSW secondary production from old and new scrap shown in parentheses.

SOURCE: Metal Statistics (various issues), Metal lgesellschaft Aktiengesellschaft

Appendix B
Country and Company Producers

Table B-1--Major Copper Producing Companies by Country

Country	Companies (m=mine, s=smelter, r=refinery)
Australia	MIM (msr), Renison Goldfields (m), ER&S (sr), Olympic Dam JV (msr)
Belgium	MHO (sr)
Brazil	Caraiba Metais (sr), CVRD (m) pending
Canada	Inco (msr), Falconbridge (msr), Noranda (msr), Highland Valley (m), BHP-Utah (m), Afton JV (m), Hudson Bay (s)
Chile	Codelco (msr), ENAMI (sr), Escondida (m) pending, Disputada (ins), Mantes Blancos (msr), Ojos del Salado (m)
Finland	Outokumpu (msr)
Germany, FR	Norddeutsche Affinerie (sr)
Indonesia	Freeport Indonesia (m)
Japan	Nippon Mining (sr), Onahama (sr), Sumitomo (sr), Mitsubishi (sr), Hibi Kyoda (sr), Dowa (msr), Mitsui (r)
Korea, Rep	Korea Mining & Smelting (sr)
Mexico	Mexicana de Cobre (ins), Cananea (ins), Medimsa (ins), Frisco (m), Cobre de Mex co (r)
Peru	SPCC (ins), Cuajone JV (m), Centromin (msr), Minero Peru (mr), Nor Peru (m)
Philippines	Atlas (m), Maricalum (m), Marcopper (m), North Davao (m), Benguet (m), Lepanto m), PASAR (sr)
PNG	Bougainvillea (m), Ok Tedi (m)
Portugal	Somincor (m)
South Africa	Palabora (msr), O'okiep (ins)
Spain	Rio Tinto Minera (sr)
Sweden	Boliden (msr)
UK	IMI Refiners (r), BICC (m)
USA	Phelps Dodge (msr), Chino JV (msr), Morenci JV (m), Cyprus (msr), Kennecott (msr), Magma (msr), Asarco (msr), Butte JV (m), Copper Range (msr), Doe Run (m), Southwire (r), Cox Creek (r), Anaconda E-R (r), Texas City (s) pending
Yugoslavia	RTB Bor (msr)
Zaire	Gecamines (msr)
Zambia	ZCCM (msr)

SOURCE: Office of Technology Assessment, 1990

Table B-2--Major Aluminum Producing Companies by Country

Country	Companies (m=mine, r=refinery, s=smelter)
Argentina	Aluminios Argentines (s)
Australia	Alcoa of Australia (mrs), Comalco (ins), Queensland Alumina (r), Boyne (s), Gove Project (mr), Tomago (s), Worsley (mr), Alcan Australia (s), Portland Smelter JV (s)
Austria	Austria Metall (s), Salzburger (s)
Bahrain	Alba (s)
Brazil	MRN (m), Alcoa Aluminio (mrs), Alcan Aluminio (mrs), CBA (mrs), Alumar (rs), Albras (s), Valesul (s), Alunorte (r) pending
Canada	Alcan (rs), Reynolds (s), Becancour (s), Alouette (s) pending
Egypt	Egyptal (s)
France	Pechiney (mrs)
Germany, FR	VAW (rs), Aluminum Oxide Stade (r), Alusuisse (rs), Hamburg Aluminum (s), Hoogovens (s)
Ghana	Ghana Bauxite (m), Valco (s)
Greece	Parnasse [m), Elbaumin (m), Greek Helikon (m), Aluminium de Grece (mrs), Hellenic Alumina (r) pending
Guinea	CBG (m), OBK (m), Friguia (mr)
Guyana	Guymine (m)
India	Bharat (mrs), Nalco (mrs), Indalco (mrs), Hindalco (mrs), Malco (rs)
Indonesia	Aneka Tambang (m), Inalum (s)
Ireland	Aughinish (r)
Italy	Aluminia SpA (s)
Jamaica	Kaiser Jamaica (m), Jamaican (mr), Alpart (mr), Clarendon Alumina JV (mr)
Japan	Nippon Light Metal (rs), Sumitomo Aluminum (r), Showa Aluminum (r)
Malaysia	Johore Mining (m)
Mexico	Alumsa (s)
Netherlands	Pechiney (s), Hoogovens (s)
New Zealand	New Zealand Al Smelters (s)
Norway	Hydro Aluminium (s), Mosal (s), Soral (s)
Sierra Leone	SIEROMCO (m)
South Africa	Alusaf (s)

Spain	**Aluminio Espanol (rs), Endasa (s)**
Suriname	**Suralco (ins), Suralco-Billiion** JV (mr)
Sweden	**Granges Aluminum (s)**
Switzerland	**Alusuisse (s)**
Turkey	Etibank (s)
UAE	**Dubai Aluminum (s)**
UK	**British Alcan (rs), Anglesey Aluminium (s)**
USA	**Alcoa (rs), Reynolds (rs), Kaiser (rs), Ormet (rs), Clarendon (r), Alumax-[Eastalco, Intalco, Mt. Holly** JV] (s), Alcan (s), Noranda (s), Columbia Falls (s), Columbia Aluminum (s), Southwire (s), Vanalco (s), Ravenswood (s), Northwest Aluminum/Martin Marietta (s)
Venezuela	Bauxiven (m), Interalumina (r), Venalum (s), Alcasa (s), [A]amsa (s), Aluyana (s), **Alisa (s), Alusur (s), Aluguay (s), Vexxal (s), Angostura (s)] pending**
Yugoslavia	Energoinvest (mrs)

SOURCE: Office of Technology Assessment, 1990

Table B-3--Major Lead Producing Companies by Country

Country	Companies (m=mine, s=smelter, r=refinery)
Australia	Pasminco (msr), MIM (ins), Aberfoyle (m) Cadjebut JV (m), Lady Loretta (m), Woodcutters JV (m)
Belgium	MHO (sr)
Canada	Cominco (msr), Faro Mine JV (m), Brunswick (m), Westmin (m), Nanisivik (m), Polaris JV (m), Noranda (sr)
Finland	Outokumpu (m)
France	Metaleurop (msr)
Germany, FR	Berzelius (msr), Metaleurop (sr), Norddeutsche Affinerie (sr)
Honduras	El Mochito (m)
Ireland	Tara Mines (m)
Italy	Nuova Samim (msr)
Japan	Dowa (msr), Nippon Mining (msr), Mitsubishi (msr), Mitsui (msr), Mitsubishi -Cominco (sr), Toho Zinc (sr), Hachinohe (sr), Sumitomo (sr)
Korea, Rep	Korea Mining & Smelting (sr), Young Poong (m)
Mexico	Medimsa (msr), Penoles (msr), Fresnillo (m), Frisco (m), Real des Angeles (m)
Morocco	Touissit (m), Djebel Aouam (m), Zellidja (sr)
Namibia	Tsumeb (msr)
Peru	Centromin (msr), Milpo (m), Atacocha (m), Raura (m), Buenaventura (m), Alianza (m), Mitsui (m), Santo Toribio (m), Nor Peru (m), Huaron (m), Volcan (m), Fundeconsa (s)
South Africa	Black Mountain (m), Billiton (m)
Spain	Metaleurop (sr), Exminesa (m), Boliden (m), Asturiana de Zinc (m), Almagrera (m), Espanola del Zinc (sr)
Sweden	Boliden (msr), Vieille-Montagne (m)
UK	Pasminco (s), Britannia (r)
USA	Doe Run (msr), Asarco (msr), Leadville JV (m), Magmont JV (m), Bunker Hill Mining (m), Greens Creek JV (m), Hecla (m), Montana Tunnels (m), Sunnyside JV (m), New Butte Mining (m), Star-Phoenix Mining (m), Red Dog JV (m) pending
Yugoslavia	RMHK Trepca (msr)

SOURCE: Office of Technology Assessment, 1990

Table B-4--Major Zinc Producing Companies by Country

Country	Companies (m=mine, r=smelter/refinery)
Australia	Pasminco (mr), MIM (m), Aberfoyle (m), Cadjebut JV (m), Lady Loretta (m), Woodcutters JV (m)
Belgium	Vieille-Montagne (r), MHO (r)
Brazil	CMM (mr), Paraibuna (r)
Canada	Brunswick (m), Falconbridge (mr), Cominco (mr), Faro Mine JV (m), Noranda (mr), Hudson Bay (mr), Nanisivik (m), Westmin (m), Daniel's Harbor JV (m), Polaris JV (m)
Denmark	Boliden (m)
Finland	Outokumpu (mr)
France	Metaleurop (mr), Vieille-Montagne (r)
Germany, FR	Metaleurop (r), Ruhr Zink (r), Berzelius (mr)
Honduras	El Mochito (m)
Ireland	Tara Mines (m)
Italy	Pertusola (r), Nuova Samim (mr)
Japan	Mitsui (mr), Dowa (m), Nippon Mining (mr), Mitsubishi (mr), Akita Zinc (r), Toho Zinc (r), Hachinohe (r), Sumitomo (r)
Korea, Rep	Korea Zinc (r), Young Poong (mr)
Mexico	Medimsa (mr), Penoles (mr), Fresnillo (m), Frisco (m), Real des Angeles (m)
Namibia	Tsumeb (mr)
Netherlands	Budelco (r)
Norway	Folldal (m), Norzink (r)
Peru	Centromin (mr), San Ignacio Morococha (m), Milpo (m), Santander (m), Volcan (m), Raura (m), Mitsui (m), Atacocha (m), Santo Toribio (m), Buenaventura (m), Alianza (m), Minero Peru (r), Nor Peru (m), Huaron (m)
South Africa	Black Mountain (m), Billiton (m), Zinc South Africa (r)
Spain	Exminesa (m), Asturiana de Zinc (mr), Boliden (m), Almagrera (m), Espanula del Zinc (r)
Sweden	Boliden (m), Vieille-Montagne (m)
Thailand	Padaeng (r)
UK	Pasminco (r)
USA	ZCA (mr), Jersey Miniere (mr), Asarco (m), Leadville JV (m), Doe Run (m), Magmont JV (m), Bunker Hill Mining (m), Greens Creek JV (m), Montana Tunnels (m), Sunnyside JV (m), Big River (r), New Butte Mining (m), Alta Gold (m), Hecla (m), Union Zinc (m), Star-Phoenix Mining (m), Cyprus (m), Red Dog JV (m) pending
Yugoslavia	RHHK Trepca (mr)
Zaire	Gecamines (mr)

SOURCE: Office of Technology Assessment, 1990

Appendix C
Company Abbreviations

DIR = Direct investment by the company metal-country (sector)
metal Al=aluminum; Cu=copper; Pb=Lead; Zn=zinc
sector m=mine; s=smelter; r=refinery (in the case of zinc, r=smelter/refinery)
PAR = Parents of the company and their shares of its ownership
SUB = Subsidiaries or joint ventures of the company and its shares of their ownership
Ownership shares for parents, subsidiaries, and joint ventures are rounded to whole percentage points. Absence of a percentage figure indicates full ownership.

Abbreviation Headquarters Location	Full Name Direct Investments and Affiliates (as of early 1990)
Aberfoyle AUSTRALIA	Aberfoyle Ltd DIR: Pb-Australia (m) Zn-Australia (m) PAR: Cominco 46%
Acec-Union Miniere BELGIUM	Acec-Union Miniere SA PAR: Societe Generale de Belgique (Belgium) owned by Cie Financiere de Suez (France) SUB: Union Mines 93%, MHO 71%, Vieille-Montagne 96%, Asturienne 55%
Afton JV CANADA	Afton Mine Joint Venture DIR: Cu-Canada (m) PAR: Teck 73%, Metall Mining 27%
Akita Zinc JAPAN	Akita Zinc Co Ltd DIR: Zn-Japan (r) PAR: Dowa 52%, Nippon Mining 14%, Sumitomo 14%, Mitsui 10%, Mitsubishi 5%, Toho Zinc 5%
Alamsa VENEZUELA	Alamsa DIR: Al-Venezuela (s) pending PAR: Austria Metall 40%, CVG 30%, Pechiney 30%
Alba BAHRAIN	Aluminum Bahrain DIR: Al-Bahrain (s) PAR: Kaiser 17%, Balco 73%
Albecour CANADA	Albecour PAR: Quebec Government SUB: Alouette ?%, Becancour 25%
Albras BRAZIL	Aluminio Brasileiro SA DIR: Al-Brazil (s) PAR: CVRD 51%, NAAC 49%
Alcan CANADA	Alcan Aluminum Ltd DIR: Al-Canada (rs), USA (s) SUB: Alcan Aluminio, British Alcan, Halco 27%, Indalco 40%, Jamaican 93%, MRN 24%, Queensland Alumina 21%, Endasa 24%, Alcan Australia 70%, Aughinish 65%, Johore Mining 70%, Nippon Light Metal 50%, Alunorte 9%
Alcan Aluminio BRAZIL	Alcan Aluminio do Brazil SA DIR: Al-Brazil (mrs) PAR: Alcan
Alcan Australia **AUSTRALIA**	Alcan Australia DIR: Al-Australia (s) PAR: Alcan 70%
Alcasa VENEZUELA	Aluminio del Caroni SA DIR: Al-Venezuela (s) PAR: CVG 72%, Reynolds 28%

Alcoa
USA
Aluminum Co of America
DIR: Al-USA (rs)
SUB: Alcoa of Australia 51%, Alcoa Aluminio 61%, Clarendon Alumina JV 50%, Halco 27%, Mosal 50%, Suralco, Alusur 40%, Alumsa 44%

Alcoa Aluminio
BRAZIL
Alcoa Aluminio do Brazil SA
DIR: A1-Brazil (mrs)
PAR: Alcoa 61%
SUB: Alumar refinery 60% & smelter 72%

Alcoa of Australia
AUSTRALIA
Alcoa of Australia Ltd
DIR: Al-Australia (mrs)
PAR: Alcoa 51%, Western Mining **44%**
SUB: Portland Smelter JV 45%

Alianza
PERU
Cia Minera Alianza SA
DIR: Pb-Peru (m) Zn-Peru (m)

Alisa
VENEZUELA
Alisa
DIR: Al-Venezuela (s) pending
PAR: CVG 20%

Almagrera
SPAIN
Minas de Almagrera
DIR: Pb-Spain (m) Zn-Spain (m)

Alouette
CANADA
Alouette
DIR: Al-Canada (s) pending
PAR: VAW ?%, Austria Metall ?%, Albecour ?%, Kobe Steel ?%, Hoogovens ?%, Marubeni ?%

Alpart
JAMAICA
Alumina Partners of Jamaica
DIR: Al-Jamaica (mr)
PAR; Kaiser 65%, Hydro Aluminum 35%

Alta Bay
USA
Alta Bay Venture
PAR: Alta Gold 60%, Echo Bay 40%
SUB: Sunnyside JV 65%

Alta Gold
USA
Alta Gold
DIR: Zn-USA (m)
PAR: Silver **King 50%, Pacific Silver 50%**
SUB: Alta Bay 60%

Aluguay
VENEZUELA
Aluguay
DIR: Al-Venezuela (s) pending

Alumar
BRAZIL
Aluminio do flaranhao SA
DIR: Al-Brazil (rs)
PAR: refinery - Alcoa Aluminio 60%, Billiton 40%; smelter - Alcoa Aluminio 72%, Billiton 28%

Alumax
USA
Alumax Inc
PAR: Amax
SUB: Intalco 75%, Eastalco 75%, Mt Holly JV 73%, **Becancour 25%**

Aluminia SpA
ITALY
Aluminia Italia SpA
DIR: Al-Italy (s)
PAR: Alumix (EFIM-Ente Partecipazioni e Finanziamento Industria Manifattureria)
SUB: Halco 6%, Sava

Aluminio Espanol
SPAIN
Aluminio Espanol SA
DIR: **Al-Spain (rs)**
PAR: Endasa 75%, Government (Instituto Nacional de Industria-INI) 19%

Aluminios Argentines
ARGENTINA
Aluminios Argentines SAIC
DIR: Al-Argentina (s)
PAR: Government 52%

Aluminium de Grece
GREECE
Aluminium de Grece SA
DIR: Al-Greece (mrs)
PAR: Pechiney 60%

Aluminium Oxide Stade
FR GERMANY
Aluminium Oxide Stade Gmbh
DIR: Al-FR Germany (r)
PAR: VAW 50%, Reynolds 50%

Alumsa
MEXICO
Grupo Aluminio SA de CV
DIR: Al-Mexico (s)
PAR: Alcoa 44%

Alunorte
BRAZIL
Alumina do Norte do Brazil SA
DIR: Al-Brazil (r) pending
PAR: CVRD 49%, MRN 26%, Alcan 9%, CBA 9%, NAAC 7%

Alusaf
SOUTH AFRICA
Alusaf Pty Ltd
DIR: Al-South Africa (s)

Alusuisse
SWITZERLAND
Swiss Aluminum Ltd
DIR: Al-Switzerland (s), FR Germany (rs)
SUB: Gove Project 70%, Nabalco 50%, Salzburger, SIEROMCO, Soral 50%, Bauxiven 4%. Interalumina 2%, Frialco 11%

Alusur
VENEZUELA
Alusur
DIR: Al-Venezuela (s) pending
PAR: CVG 40%, Alcoa 40%, Sural 20%

Aluyana
VENEZUELA
Aluyana
DIR: Al-Venezuela (s) pending
PAR: CVG ?%, Italimpianti ?%

Amax
USA
Amax Inc
PAR: Chevron IB%
SUB: Alumax, Daniel's Harbor JV 37%, Fresnillo 40%

Amoco
USA
Amoco Minerals Co
PAR: Amoco Corp.
SUB: Ok Tedi 30%

AMP
AUSTRALIA
Australian Mutual Provident Society
SUB: Gove 30%. Comalco 12%

Anaconda E-R
USA
Anaconda Environ-Refining
DIR: CU-USA (r)

Aneka Tambang
INOONESIA
PT Aneka Tambang
DIR: Al-Indonesia (m)
PAR: Government

Anglesey Aluminum
UK
Anglesey Aluminium Ltd
OIR: Al-UK *(s)*
PAR: RTZ 51%, Kaiser 49%

Anglo American Gold
SOUTH AFRICA
Anglo American Gold Investment Co Ltd
PAR: Anglo American S Africa 49%
SUB: GFSA 11%

Anglo American S Africa
SOUTH AFRICA
Anglo American Corp of South Africa Ltd
PAR: De Beers 38%
SUB: Oe Beers 34%, Minorco 40%, Hantos Blancos 79%, GFSA 9%, Anglo American Gold 49%, Palabora ?%

Angostura
VENEZUELA
Angostura
DIR: Al-Venezuela (s) pending

Asarco
USA
Asarco Inc
DIR: CU-USA (msr) Pb-USA (msr) Zn-USA (m)
PAR: MIM 25%
SUB: SPCC 52%, M1fl 19%, Medimsa 34%, Leadville JV 50%, Butte JV 50%, Nor Peru 80%

Asturiana de Zinc
SPAIN
Asturiana de Zinc SA
DIR: Pb-Spain (m) Zn-Spain (mr)
SUB: Exminesa 30%

Asturienne
BELGIUM
CieRoyale Asturienne des Mines SA
PAR: Acec-Union Miniere 55%
SUB: Touissit 50%, Pancontinental 10%, Djebel Aouam 67%

Atacocha
PERU
Cia Minera Atacocha SA
DIR: Pb-Peru (m) Zn-Peru (m)
SUB: Huaron 5%

Atlas
PHILIPPINES
Atlas
DIR: Cu-Philippines (m)
SUB: PASAR ?%

Aughinish
IRELAND
Aughinish Alumina Ltd
DIR: Al-Ireland (r)
PAR: Alcan 65%, Billiton 35%

Austria Metall
AUSTRIA
Austria Metall AG
DIR: Al-Austria (s)
PAR: Government
SUB: **Alouette ?%, Alamsa 40%**

Balco
BAHRAIN
Bahrain Saudi Aluminum Marketing Co
PAR: Bahrain Government 74%, Saudi Basic Industries Corp (SABIC) 26%
SUB: Alba 73%

Bauxiven
VENEZUELA
Bauxita de Venezolana CA
DIR: Al-Venezuela (m)
PAR: CVG 96%, Alusuisse 4%

Becancour
CANADA
Aluminum Becancour Inc
DIR: Al-Canada (s)
PAR: Pechiney 25%, Reynolds 25%, Alumax 25%, Albecour 25%

Benguet
PHILIPPINES
Benguet
DIR: Cu-Philippines (m)

Berzelius
FR GERMANY
Berzelius Metallhutten Gmbh
DIR: **Pb-FR Germany** (msr) Zn-FR Germany (mr)
PAR: MG

Bharat
INDIA
Bharat Aluminium Co **Ltd**
DIR: Al-India (mrs)
PAR: Government

BHP
AUSTRALIA
Broken Hill Proprietary Co Ltd
SUB: BHP-Utah. Ok Tedi 30%, Cadjebut JV 58%, Escondida 58%

BHP-Utah
USA
BHP-Utah International Inc
DIR: Cu-Canada (m)
PAR: BHP

BICC
UK
B. I.C.C. Metals Ltd
DIR: CU-UK (m)

Big River
USA
Big River Minerals Co
DIR: Zn-USA (r)

Billiton
NETHERLANDS
Billiton International Metals
DIR: Pb-South Africa (m) Zn-South Africa (m)
PAR: Shell
SUB: Halco 6%, MRN 10%, Valesul 45%, Worsley 38%, Cadjebut JV 42%, Budelco 50%, Aughinish 35%, Cuajone JV 9%, **Alumar ref 40% & smelt 28%, Suralco-Billiton JV** mine 76% & ref 45%

Black Mountain
SOUTH AFRICA
Black Mountain Mineral Development Co Pty Ltd
DIR: Pb-South Africa (m) Zn-South Africa (m)
PAR: GFSA 55%, Phelps Dodge 45%

Boliden
SWEDEN
Boliden AB
DIR: Cu-Sweden (msr) Pb-Sweden (msr), Spain (m) Zn-Sweden (m], Spain (m), Denmark (m)
PAR: Trelleborg 68%
SUB: Norzink 50%, Faro Mine JV 8%

Bougainvillea
PAPUA NEW GUINEA
Bougainvillea Copper Ltd
DIR: CU-PNG (m)
PAR: CRA 54%, **Government 20%**

Boyne
AUSTRALIA
Boyne Smelters Ltd
DIR: Al-Australia (s)
PAR: Comalco 30%, Kaiser 20%, Japanese Consortium 50%

BP
UK
BP **Minerals International Ltd**
PAR: British Petroleum Co Plc
SUB: Olympic Dam JV 49%

Brascade Resources
CANAOA
Brascade Resources
PAR: Brascan *JO%*
SUB: Noranda 46%, Westmin 62%

Brascan
CANADA
Brascan Ltd
SUB: Brascade Resources 70%

Britannia
UK
Britannia Refined Metals Ltd
DIR: Pb-UK (r)
PAR: MIM

British Alcan
UK
British Alcan Aluminum Ltd
DIR: Al-UK *(rS)*
PAR: Alcan
SUB: **Frialco** 11%, Ghana **Bauxite 45%**

BRPM
MOROCCO
Bureau de Recherches et de Participations Hinieres
PAR: Government
SUB: Djebel Aouam 33%

Brunswick
CANADA
Brunswick Mining and Smelting Corp Ltd
DIR: Pb-Canada (m) Zn-Canada (m)
PAR: Noranda 64%

Budelco
NETHERLANDS
Budelco BV
DIR: Zn-Netherlands (r)
PAR: Billiton 50%, Pasminco 50%

Buenaventura
PERU
Cia **de t4inas Buenaventura SA**
OIR: Pb-Peru (m) Zn-Peru (m)
PAR: Cerro Copper 34%, World Bank 5%, Centromin 18%

Bunker Hill Mining
CANADA
Bunker Hill Mining
DIR: Pb-USA (m) Zn-USA (m)

Butte JV
USA
Butte Mine Joint Venture
DIR: CU-USA (m)
PAR: Montana Resources 50%, Asarco 50%

C. Itoh
JAPAN
C. Itoh & Co **Ltd**
SUB: Kobe Alumina ?%, PASAR 6%

Cadjebut JV
AUSTRALIA
Cadjebut Mine Joint Venture
DIR: Pb-Austral ia (m) Zn-Australia (m)
PAR: 13HP 58%, Billiton 42%

Cananea
MEXICO
Cia Minera de Cananea SA
DIR: Cu-lexico (ins)
PAR: Government 90%
SU8: Cobre de Mexico ?%

CAP
JAMAICA
Clarendon Alumina Production Ltd
PAR: Jamaica Bauxite Mining
SU8: Clarendon Alumina JV 50%

Caraiba Metais
BRAZIL
Caraiba Metais SA - Ind e Com
DIR: Cu-Brazil (sr)
PAR: Government 98%

CBA
BRAZIL
Cia Brasileira de Aluminio
DIR: Al-Brazil (mrs)
PAR: Votorantim 80%, Government 20%
SUB: MRN 10%, Alunorte 9%

CBG
GUINEA
Compagnie des Bauxites de Guinea
DIR: Al-Guinea (m)
PAR: Halco 51%, Government 49%

Centromin
PERU
Empresa tiinera del Centro del Peru SA
DIR: Cu-Peru (msr) Pb-Peru (msr) Zn-Peru (mr)
PAR: Government
SUB: Buenaventura 18%

Cerro Copper
USA
Cerro Copper Products Co
PAR: Marmon
SUB: SPCC 21%, Buenaventura 34%

Chevron
USA
Chevron Corp
SUB: Amax 18%

Chino JV
USA
Chino Joint Venture
DIR: CU-USA (msr)
PAR: Phelps Dodge 67%, Mitsubishi 33%

Clarendon Alumina JV
JAMAICA
Clarendon Alumina Joint Venture
DIR: **Al-Jamaica (mr)**
PAR: Alcoa 50%. CAP 50%

Clarendon Ltd
SWITZERLAND
Clarendon Ltd
DIR: Al-USA (r), tolling contracts with Drmet and Northwest Aluminum
PAR: t4arc Rich and Co (Switzerland)
SUB: Mt Holly JV 27%

CM
BRAZIL
Cia Hineira de Metais
DIR: Zn-Brazil (mr)
PAR: Votarantim

Cobre de Mexico
MEXICO
Cobre de Mexico
DIR: Cu-Mexico (r)
PAR: Government (Nacional Financier) ?%, Cananea ?%, various copper fabricators ?%

Codelco
CHILE
Corpacion Nacional del Cobre de Chile
DIR: Cu-Chile (msr)
PAR: Government

Columbia Aluminum
USA
Columbia Aluminum Corp
DIR: Al-USA *(S)*
PAR: employees 30%

Columbia Falls
USA
Columbia Falls Aluminum Co
DIR: Al-USA *(S)*
PAR: Montana Aluminum Investors

Comalco
AUSTRALIA

(hmalco Ltd
DIR: Al-Australia (ins)
PAR: CRA 67%, AMP 12%
SUB: Boyne 30%, Halco 8%, Queensland Alumlna 30%, New Zealand Al Smelters 79%

Cominco
CANADA

Cominco Ltd
DIR: Pb-Canada (msr) Zn-Canada (mr)
PAR: Nunachiaq 40%, Mitsui 3%
SUB: Aberfoyle 46%, Exminesa 48%, Mitsubishi-Cominco 45%, Highland Valley 50%, Magmont JV 50%, Red Dog JV (development and operations), Pine Point 51%. Polaris JV 55%

Cons Gold Fields
UK

Consolidated Gold Fields plc
PAR: Hanson PLC
SUB: Newmont 49%, Renison Goldfields 46%

Copper Range
USA

Copper Range Co
DIR: CU-USA (msr)
PAR: Metall Mining

Cox Creek
USA

Cox Creek Refining
DIR: CU-USA (r)
PAR: Mitsubishi 20%, Southwire 20%, Halstead Industries 20%

CRA
AUSTRALIA

CRA Ltd
PAR: RTZ 49%
SUB: Comalco 67%, Bougainvillea 54%, Pasminco 40%

CSR
AUSTRALIA

CSR Ltd
SUB: Gove 70%

Cuajone JV
PERU

Cuajone Mine Joint Venture
DIR: Cu-Peru (m)
PAR: SPCC 91%, Billiton 9%

Curragh
CANADA

Curragh Resources Corp
PAR: Frame Mining Corp (Clifford Frame) 98%
SUB: Faro Mine JV 92%

CVG
VENEZUELA

Corp Venezolana de Guayana
PAR: Government
SUB: Alcasa 72%, Interalumina 98%, Venalum 80%, Bauxiven 96%, Alamsa 30%, Alisa 20%, Alusur 40%, Aluyana ?%

CVRD
BRAZIL

Cia Vale do Rio Doce
DIR: **Cu-Brazil (m) pending**
PAR: Government 56%
SUB: Albras 51%, Alunorte 49%, PIRN 46%, Valesul 55%

Cyprus
USA

Cyprus Minerals Co
DIR: CU-USA (msr) Zn-USA (m)

Daniel's Harbor JV
CANADA

Daniel's Harbor Mine Joint Venture
DIR: Zn-Canada (m)
PAR: Teck 63%, Amax 37%

De Beers
SOUTH AFRICA

De **Beers Consolidated** Mines
PAR: Anglo American S Africa 34%
SUB: Anglo American S **Africa 38%, Plinorco 21%, Palabora ?%**

Degussa
FR GERMANY

Degussa AG
SUB: Norddeutsche Affinerie 30%, Ok Tedi 9%

Disputada
CHILE

Cia **Minera Disputada de las Condes SA**
DIR: Cu-Chile (ins)
PAR: Exxon Coal and Minerals

Djebel Aouam
MOROCCO

Ste **Miniere du Djebel Aouam**
DIR: Pb-Horocco (m)
PAR: BRPM 33%, Asturienne 67%

Doe Run USA	Doe Run Co DIR: CU-USA (m) Pb-USA (msr) Zn-USA (m) PAR: Fluor
Dowa JAPAN	Dowa Mining Co Ltd DIR: Cu-Japan (msr) Pb-Japan (msr) Zn-Japan (m) SUB: Akita Zinc 52%, Hachinohe 20%, Onahama 30%
Dubai Aluminum UNITED ARAB EMIRATES	Dubai Aluminum Co Ltd DIR: A1-UAE (S) PAR: Government 80%, Southwire 8%, Nissho Iwai 8%
Eastal co USA	Eastalco Aluminum Co DIR: Al-USA (S) PAR: Alumax 75%, Mitsui 11%, Toyo Sash 7%, Yoshida Kogya KK 7%
Echo Bay USA	Echo Bay SUB: Alta Bay 40%
Egyptal EGYPT	Aluminum Co of Egypt DIR: Al-Egypt (S) PAR: Government
El Mochito HONDURAS	El Mochito mine DIR: Pb-Honduras (m) Zn-Honduras (m) PAR: Metall Mining
E 1 baumi n GREECE	Eleusis Bauxite Mines Mining Industrial & Shipping Inc DIR: Al-Greece (m) PAR: Government
E 1 kern NORWAY	Elkem AIS Norway PAR: Kvaerner Industries A/S SUB: Mosal 50%
ENAH I CHILE	Empresa Nacional de Mineria DIR: Cu-Chile (sr) PAR: Government
Endasa SPAIN	Empresea Nacional del Aluminio SA DIR: Al-Spain (s) PAR: Government (Instituto Nacional de Industria-INI) 73%, Alcan 24% SUB: Aluminio Espanol 75%
Energoinvest YUGOSLAVIA	Energoinvest DIR: Al-Yugoslavia (mrs) PAR: Government
ER&S AUSTRALIA	Electrolytic Refining & Smelting Co of Australia Ltd DIR: Cu-Austral ia (sr) PAR: Pasminco 60%, Japanese consortium (led by Furukawa) 40%
Escondida CHILE	Minera Escondida Ltd DIR: Cu-Chile (m) pending PAR: BHP 58%, RTZ 30%, Japan Escondida 10%, World Bank 3%
Espanola del Zinc SPAIN	Espanola del Zinc SA DIR: **Pb-Spain (sr) Zn-Spain (r)** **PAR: hletal Quimica del Nervion 31%**
Etibank TURKEY	**Etibank** **DIR: Al-Turkey (s)** **PAR: Government**
Exalas Resources **USA**	**Exalas Resources** **PAR: t4itsubishi** **SUB: Greens Creek** JV 13%

Exminesa SPAIN	**Exploration Minera International Espana SA** **DIR: Pb-Spain (m) Zn-Spain (m)** **PAR: Cominco 48%, Asturiana de Zinc 30%**
Exxon Coal and Minerals USA	Exxon Coal and Minerals Co PAR: Exxon **Corp** **SUB: Disputada**
Falconbridge CANADA	**Falconbridge Ltd** **DIR: Cu-Canada (msr) Zn-Canada (mr)** **PAR: Noranda 50%, Trelleborg 50%**
Faro Mine JV CANADA	**Faro** Mine Joint Venture **DIR: Pb-Canada (m) Zn-Canada (m)** **PAR: Curragh 92%, Boliden 8%**
F1uor USA	**Fluor** Corp **SUB: Doe** Run
Fol1dal NORWAY	Folldal Verk A/S DIR: Zn-Norway (m)
Freeport Indonesia USA	Freeport Indonesia Inc DIR: Cu-Indonesia (m) PAR: Freeport-McMoRan 85%, Government 9%, Norddeutsche Affinerie 4%
Freeport McMoRan USA	Freeport-McMoRan Inc SUB: Freeport Indonesia 85%
Fresnillo MEXICO	Cia Fresnillo SA de CV DIR: Pb-Mexico (m) Zn-Mexico (m) PAR: Penoles 60%, Max 40%
Frialco CAYMAN ISLANDS	Frialco SA PAR: Noranda 38%, Pechiney 36%, Alusuisse 11%, British Alcan 11%, **VAW 5%** **SUB:** Friguia 51%
Friguia GUINEA	Societe d'Economie Mixte Friguia DIR: Al-Guinea (mr) PAR: Frialco 51%, Government 49%
Frisco MEXICO	Empresas Frisco SA de CV DIR: Cu-Mexico (m) Pb-Mexico (m) Zn-Mexico (m) SU8: Real des Angeles 33%
Fundeconsa **PERU**	Fundicion de Concentrados SA DIR: Pb-Peru (s)
Furukawa **JAPAN**	Furukawa Co Ltd SUB: Hibi Kyodo 16%, Onahama **8%, ER&S ?%**
Gecamines **ZAIRE**	La **Generale des Carrieres et des Hines du Zaire** **DIR: Cu-Zaire** (msr) **Zn-Zaire** (mr) PAR: Government
GFSA **SOUTH AFRICA**	Gold Fields of South Africa Ltd PAR: Anglo American Gold 11%, Anglo American S Africa 9% SUB: O'okiep 81%, Black Mountain 55%, Zinc South Africa 65%, Tsumeb 76%
Ghana Bauxite **GHANA**	Ghana Bauxite Co Ltd DIR: Al-Ghana (m) PAR: Government 55%, British Alcan 45%
Gove **AUSTRALIA**	Gove Aluminium Ltd PAR: CSR 70%, AMP 30% SUB: Gove Project 30%, Nabalco 50%, Tomago 35%
Gove Project **AUSTRALIA**	Gove Project DIR: Al-Australia (mr) PAR: Alusuisse 70%, Gove 30%, managed by Nabalco

Granges Aluminum
SWEDEN
Granges Aluminum
DIR: Al-Sweden (s)
PAR: Granges AB

Greek Helikon
GREECE
Greek Helikon Bauxites GL Barlos SA
DIR: Al-Greece (m)

Greens Creek JV
USA
Greens Creek Mine Joint Venture
DIR: Pb-USA (m) Zn-USA (m)
PAR: RTZ 53%, Hecla 28%, Exalas Resources 13%, CSX Oil & Gas 6%

Guymine
GUYANA
Guyana Mining Enterprise Ltd
DIR: Al-Guyana (m)
PAR: Government (Bauxite Industry Development Co-Bidco)

Hachinohe
JAPAN
Hachinohe Smelting Co Ltd
DIR: Pb-Japan (sr) Zn-Japan (r)
PAR: Mitsui 50%, Dowa 20%, Nippon Mining 10%, Mitsubishi 10%, Toho Zinc 5%, Nisso Smelting 5%

Halco
USA
Halco (Mining) Inc
PAR: Alcan 27%, Alcoa 27%, Pechiney 10%, VAU 10%, Comalco 8%, Aluminia SpA 6%, Reynolds 6%, Billiton 6%
SUB: CBG 51%

Hamburg Aluminum
FR GERMANY
Hamburger Aluminiumwerke GmbH
DIR: A1-FR Germany (s)
PAR: Reynolds 33%, VAW 33%, City of Hamburg 33%

Hecla
USA
Hecla Mining Co
DIR: Pb-USA (m) Zn-USA (m)
SUB: Greens Creek JV 28%

He?lenic Alumina
GREECE
Hellenic Alumina (ELVA)
DIR: Al-Greece (r) pending

Hibl Kyodo
JAPAN
Hibi Kyodo Smelting Co Ltd
DIR: Cu-Japan (sr)
PAR: Mitsui 64%, Nittetsu 20%, Furukawa 16%

Highland Valley
CANADA
Highland Valley Copper
DIR: Cu-Canada (m)
PAR: Cominco 50%, **Rio Algom 34%, Teck 14%, Highmont 3%**

Highmont
CANADA
Highmont Mining Co
SUB: Highland Valley 3%

Hindalco
INDIA
Hindustan Aluminium Corp
DIR: Al-India (mrs)

Hoogovens
NETHERLANDS
Koninklijke Nederlandsche Hoogovens en Staalfabrieken NV
DIR: A1-FR Germany (s), Netherlands (s)
SUB: Alouette ?%

Horsehead
USA
Horsehead Industries
SUB: ZCA

Huaron
PERU
Cia **Minera Huaron SA**
DIR: Pb-Peru (m) Zn-Peru (m)
PAR: Metaleurop 17%, Atacocha 5%

Hudson Bay
CANADA
Hudson Bay Mining and Smelting Co Ltd
DIR: Cu-Canada (s) Zn-Canada (mr)
PAR: Inspiration Resources

Hydro Aluminum
NORWAY
Hydro Aluminium A/S
DIR: Al-Norway (s)
PAR: Norsk Hydro
SUB: Alpart 35%

Imetal FRANCE	Imetal SA SUB: Metaleurop 15%
IMI Refiners UK	IMI Refiners Ltd DIR: CU-UK (r)
IMM MEXICO	Grupo Industrial Minera Mexico SA de CV SUB: Medimsa 66%
Inalum INDONESIA	PT Indonesia Ashahan Aluminum DIR: Al-Indonesia (s) PAR: Nippon Asahan Aluminium Co Ltd (Japanese Consortium) 59%, Government 41%
Inco CANADA	Inco Ltd OIR: Cu-Canada (msr)
Indalco INDIA	Indian Aluminium Co Ltd DIR: Al-India ***(mrs)*** PAR: Alcan 40%
Inspiration Resources USA	Inspiration Resources Corp PAR: Minorco 57% equity & 43% voting SUB: Hudson Bay
Intal co USA	Intalco Aluminum Co OIR: Al-USA **(S)** PAR: Alumax 75%, Mitsui 11%, Toyo Sash 7%, Yoshida Kogya KK 7%
Interalumina VENEZUELA	Interamericana de Alumina OIR: Al-Venezuela (r) PAR: CVG 98%, Alusuisse 2%
Jamaica Bauxite Mining JAMAICA	Jamaica Bauxite Mining Ltd PAR: Government SUB: **CAP, Kaiser Jamaica 51%, Jamaican 7%**
Jamalcan JAMAICA	**Alcan Jamaica Co** **DIR: Al-Jamaica (mr)** **PAR: Alcan 93%, Jamaica Bauxite Mining 7%**
Japan Escondida CHILE	**Japan Escondida Corp** **PAR: Mitsubishi 60%, Nippon Mining 20%** **SUB: Escondida 10%**
Jersey Miniere USA	Jersey Miniere Zinc Co DIR: Zn-USA (mr) PAR: Union Zinc
Johore Mining MALAYSIA	Johore Mining and Stevedoring Co Sdn Bhd DIR: Al-Malaysia (m) PAR: Alcan 70%
Kaiser USA	Kaiser Aluminum & Chemical Corp DIR: Al-USA (rs) PAR: Maxxam SUB: Alpart 65%, Anglesey Aluminum 49%, Boyne 20%, Kaiser Jamaica 49%, Queensland Alumina 28%, Alba 17%, Valco 90%
Kaiser Jamaica JAMAICA	Kaiser Jamaica Bauxite Co DIR: Al-Jamaica (m) PAR: Jamaica Bauxite Mining 51%, Kaiser 49%
Kennecott USA	Kennecott Corp OIR: CU-USA (msr) PAR: RTZ
Kobe Alumina AUSTRALIA	Kobe Alumina **Associates (Australia) Pty Ltd** **PAR: C. Itoh ?%, Nissho Iwai 35%** **SUB:** Worsley 10%

Kobe Steel
JAPAN
Kobe Steel Ltd
SUB: Alouette ?%

Korea Mining & Smelting
REP KOREA
Korea Mining & Smelting Co Ltd
DIR: Cu-Rep. Korea (sr) Pb-Rep Korea (sr)

Korea Zinc
REP KOREA
Korea Zinc Co
DIR: Zn-Rep Korea (r)

Lady Loretta
AUSTRALIA
Lady Loretta Co Pty Ltd
DIR: Pb-Australia (m) Zn-Australia (m)
PAR: Pancontinental 51%, Outokumpu 49%

Leadville JV
USA
Leadville Mine Joint Venture (Black Cloud)
DIR: Pb-USA (m) Zn-USA (m)
PAR: Asarco 50%, Newnont 50%

Lepanto
PHILIPPINES
Lepanto Consolidated Mining Co
DIR: Cu-Philippines (m)

Magma
USA
Magma Copper Co
DIR: CU-USA (msr)

Magmont JV
USA
Magmont Uine Joint Venture
DIR: Pb-USA (m) Zn-USA (m)
PAR: Cominco (Cominco American) 50%, Oresser Industries 50%

Malco
India
Madras Aluminum Co Ltd
DIR: Al-India (rs)

Mantes Blancos
CHILE
Empresa Minera de Mantes Blancos SA
DIR: Cu-Chile (msr)
PAR: Anglo American S Africa 79%

Harcopper
PHILIPPINES
Marcopper Mining Corp
DIR: Cu-Philippines (m)
PAR: Placer Dome 40%

Maricalum
PHILIPPINES
Maricalum Mining Corp
DIR: Cu-Philippines (m)

Marmon
USA
The Marmon Group, Inc
SUB: Cerro Copper, Raura 60%

Martin Marietta
USA
Martin Marietta Corp
SUB: leasing The Dalles, OR aluminum smelter to Northwest Aluminum

Marubeni
JAPAN
Marubeni Corp
SUB: Alouette ?%, PASAR 16%

Maxxam
USA
Maxxam Group Inc
SUB: Kaiser

Medimsa
MEXICO
Mexico Desarrollo Industrial Minero
DIR: Cu-Mexico (ins) Pb-Mexico (msr) Zn-Mexico (mr)
PAR: It4M 66%, Asarco 34%
SUB: Mexicana de Cobre 91%

Metaleurop
FRANCE
Metaleurop
DIR: Pb-France (msr), FR Germany (sr), Spain (sr) Zn-France (mr), FR Germany (r)
PAR: Preussag 51%, Imetal 15%
SUB: Huaron 17%, Pertusola 51%

Metall Mining
CANADA
Metall Mining Corp.
PAR: PIG 63%
SUB: Copper Range, Nunachiaq 25%, Teck 10%, Ok Tedi 9%, Afton JV 27%, MIH 4%, El Mochito

Metallgesellschaft
see klG

Mexicana de Cobre
MEXICO

Mexicana de Cobre SA
DIR: Cu-Mexico (ins)
PAR: Medimsa 91%, National Mine and Metallurgical Workers Union 9%

MG
FR GERMANY

Metallgesellschaft AG
PAR: Allgemeine Verwaltungsges fur Industriebeteiligungen GmbH 25%, Kuwait Government 10%, Kuwait Petroleum Co 10%, MIM 3%
SUB: Metall Mining 63%, Norddeutsche Affinerie 35%, Ruhr Zinc 50%, Berzelius

MHO
BELGIUM

Metallurg.ie Hoboken-Overpelt
DIR: Cu-Belgium (sr) Pb-Belgium (sr) Zn-Belgium (r)
PAR: Acec-Union Miniere 71%, Pancontinental 4%
SUB: Union Mines 6X

Milpo
PERU

Cia Minera Milpo SA
DIR: Pb-Peru (m) Zn-Peru (m)

HIM
AUSTRALIA

HIM Holdings Ltd
OIR: **Cu-Australia (msr) Pb-Australia (ins) Zn-Australia (m)**
PAR: Asarco 19%, Preussag 4%, Netall Mining 4%
SUB: Asarco 25%, Nunachiaq 25%, Norddeutsche Affinerie 35%, Ruhr Zinc 50%, Teck 5%, MG 3%, Brittania

Minero Peru
PERU

Empresa Minera del Peru SA
DIR: Cu-Peru (mr) Zn-Peru (r)
PAR: Government

Minorco
LUXEMBOURG

Minerals and Resources Corp Ltd
PAR: *Anglo* American S Africa 40%, De Beers 21%
SUB: Inspiration Resources 5?% equity & 43% voting

Mitsubishi
JAPAN

Mitsubishi Metal Corp
OIR: **Cu-Japan (sr) Pb-Japan (msr) Zn-Japan (mr)**
SUB: Chino JV 33%, Mitsubishi-Cominco 55%, Akita Zinc 5%, Onahama 49%, Hachinohe 10%, Exalas Resources, Texas City 51%, Cox Creek 20%, Japan Escondida 80%

Mitsubishi -Cominco
JAPAN

Mitsubishi Cominco Smelting
OIR: Pb-Japan (sr)
PAR: Mitsubishi 55%, Cominco 45%

t4itsui
JAPAN

Mitsui Mining and Smelting Co Ltd
OIR: Cu-Japan (r) Pb-Japan (msr), Peru (m) Zn-Japan (mr), Peru (m)
SUB: Cominco 3%, Akita Zinc 10%, Hachinohe 50%, Hibi Kyodo 64%, Intalco 11%, Eastalco 11%

Montana Resources
USA

Montana Resources Inc
SUB: Butte JV 50%

Montana Tunnels
USA

Montana Tunnels
OIR: Pb-USA (m) Zn-USA (m)
PAR: Pegasus Gold

Morenci JV
USA

Morenci Mine Joint Venture
DIR: CU-USA (m)
PAR: Phelps Oodge 85%, Sumitomo 15%

Mosal
NORWAY

Mosal *Alumirtium SA*
DIR: Al-Norway (s)
PAR: Elkem 50%, Alcoa 50%

MRN
BRAZIL

Mineracao Rio do Norte SA
OIR: Al-Brazil (m)
PAR: CVRO 46%, Alcan 24%, CBA 10%, Billiton 10%, Reynolds 5%, Norsk Hydro 5%
SUB: Alunorte 26X

Mt HoIly JV
USA
Mt Holly Smelter Joint Venture
DIR: Al-USA (S)
PAR: Alumax 73%, Clarendon Ltd 27%

NAAC
BRAZIL
Nippon Amazon Aluminum Co Ltd
PAR: Japanese Consortium
SUB: Albras 49%, Alunorte 7%

Nabal co
AUSTRALIA
Nabalco Pty Ltd
PAR: Alusuisse 50%, Gove 50%
SUB: manages the Gove Project

Nal co
INDIA
National Aluminium Co Ltd
DIR: Al-India (mrs)
PAR: **Government**

NANA
USA
NANA Development Corp (an Alaskan Native corp)
SUB: Red Dog JV **(owns** mineral rights)

Nani si v i k
CANADA
Nanisivik Mines Ltd
DIR: Pb-Canada (m) Zn-Canada (m)
PAR: Mineral Resources International Ltd 82%

NBHH
AUSTRALIA
North Broken Hill Holdings Ltd
SUB: Pasminco 40%

New Butte Mining
USA
New Butte Mining
DIR: Pb-USA (m) Zn-USA (m)

New Zealand Al Smelters
NEW ZEALAND
New Zealand Aluminium Smelters Ltd
DIR: Al-New Zealand (s)
PAR: **thnalco** 79%

Newmont
USA
Newnont Mining Corp
PAR: Cons Gold Fields 49%
SU8: SPCC 11%, **Leadville** JV 50%

Nicron
AUSTRALIA
Nicron Resources Ltd
SUB: Woodcutters JV 77%

Nippon Light Metal
JAPAN
Nippon Light Metal Co Ltd
DIR: Al-Japan (rs)
PAR: Alcan 50%

Nippon Mining
JAPAN
Nippon Mining
DiR: Cu-Japan (sr) Pb-Japan (msr) Zn-Japan (mr)
SUB: Akita Zinc 14%, Hachinohe 10%, Japan Escondida 20%

Nippon Steel
JAPAN
Nippon Steel
SUB: Nittetsu 28%

Nissho Iwai
JAPAN
Nissho Iwai Corp
SUB: Kobe Alumina 35%, Dubai Aluminum 8%

NIttetsu
JAPAN
Nittetsu Mining Co Ltd
PAR: Nippon Steel 28%
SUB: Hibi Kyodo 20%

Nor Peru
PERU
Corp Minera Nor Peru
DIR: Cu-Peru (m) Pb-Peru (m) Zn-Peru (m)
PAR: Asarco 80%

Noranda
CANADA
Noranda Inc
DIR: Al-USA (S) Cu-Canada (msr) Pb-Canada (sr) Zn-Canada (mr)
PAR: Brascade Resources 46%
SUB: Falconbridge 50%, Brunswick 64%, Frialco 38%

Norddeutsche Affinerie
FR GERMANY
Norddeutsche Affinerie AG
DIR: CU-FR Germany (sr) Pb-FR Germany (sr)
PAR: MG 35%, MIM 35%, Degussa 30%
SUB: Freeport Indonesia 4%

Norsk Hydro
NORWAY
Norsk Hydro
PAR: Government 51%
SUB: Hydro Aluminum, MRN 5%, Soral 50%

North Davao
PHILIPPINES
North Davao Mining Corp
DIR: Cu-Philippines (m)

Northwest Aluminum
USA
Northwest Aluminum Corp
DIR: Al-USA **(S)**
PAR: leasing The Dalles, OR aluminum smelter from Martin Marietta

Norzink
NORWAY
Norzink AS
DIR: Zn-Norway (r)
PAR: Boliden 50%, RTZ 50%

Nunachi aq
CANADA
Nunachiaq Inc
PAR: Teck 50%, Metall Mining 25%, MIM 25%
SUB: Cominco 40%

Nuova Samim
ITALY
Sta Azionaria Minero Metallurgic SPA
DIR: Pb-Italy (msr) Zn-Italy (mr)
PAR: Government (Ente Nazionae Idrocarburi-ENI) 51%, Snare 49%

O'okiep
SOUTH AFR CA
O'okiep Copper Co Ltd
DIR: Cu-South Africa (ins)
PAR: GFSA 81%

OBK
GUINEA
Offices de Bauxites de Kindia
DIR: Al-Guinea (m)
PAR: Government

Ojos del Salado
CHILE
Compania Minera Ojos del Salado SA
DIR: Cu-Chile (m)
PAR: Phelps Dodge

Ok Tedi
PAPUA NEW GUINEA
Ok Tedi Miriing **Ltd**
DIR: CU-PNG (m)
PAR: BHP 30%, Amoco 30%, Government 15%, and through Star Mountains Holdings (Metall Mining 9%, Degussa 9%, Deutsche Ges fur Wirtschaftliche **Zusamnenabeit 8%)**

Olympic Dam JV
AUSTRALIA
Olympic Dam Mine Joint Venture
DIR: Cu-Australia (msr)
PAR: Western Mining 51%, BP 49%

Onahama
JAPAN
Onahama Smelting & Refining Co Ltd
DIR: Cu-Japan (sr)
PAR: Mitsubishi 49%, Oowa 30%, Furukawa 8%

Ormet
USA
Ormet Corp
DIR: Al-USA (rs)
PAR: Ohio River Associates Inc

Outokumpu
FINLANO
Outokumpu Oy
DIR: Cu-Finland (msr) Pb-Finland (m) Zn-F~nland (mr)
PAR: Government (direct) 61%, Government (Kansanelakelaitos pension plan) 14%
SUB: Tara Mines 75%, Lady Loretta 49%

Padaeng
THAILAND
Padaeng Industry Co Ltd
DIR: Zn-Thailand (r)

Palabora
SOUTH AFRICA
Palabora Mining Co Ltd
DIR: Cu-South Africa (msr)
PAR: RTZ 39%, Anglo American S Africa ?%, Oe Beers ?%

Pancontinental
AUSTRALIA
Pancontinental Mining Ltd
PAR: Asturienne 10%, MHO 4%
SUB: Lady Loretta 51%

Paraibuna
BRAZIL

Cia **Paraibuna de Metais**
DIR: Zn-Brazil (r)
PAR: Financiamentos e Participacoes (FIBASE) ?%

Parnasse
GREECE

Bauxites Parnasse Mining Co
DIR: Al-Greece (m)
PAR: Eliopoulos-Kyriacopoulos Group

PASAR
PHILIPPINES

Philippine Associated Smelting and Refining Corp
DIR: Cu-Philippines (sr)
PAR: Government (National Development Corp) 40%, Marubeni 16%, Sumitomo 10%, C. Itoh 6%, Philippine copper producers (led by Atlas) 23%, World Bank 5%

Pasminco
AUSTRALIA

Pasminco Ltd
DIR: Pb-Australia (msr), UK (s) **Zn-Australia** (mr), UK (r)
PAR: CRA 40%, NBHH 40%
SUB: Budelco 50%, ER&S 60%

Pechiney
FRANCE

Pechiney
DIR: Al-France (mrs), Netherlands (s)
SUB: Aluminum Greece 60%, Becancour 25%, Halco 10%, Queensland Alumina 20%, Tomago 35%, Alamsa 30%, Frialco 36%

Pegasus Gold
USA

Pegasus Gold Inc
SUB: Montana Tunnels

Penarroya
FRANCE

Ste Miniere et Metallurgique de Penarroya SA
SUB: merged with the lead and zinc assets of Preussag and renamed Metaleurop in 1988

Penol es
MEXICO

Industrial Penoles SA de CV
DIR: Pb-Mexico (msr) **Zn-Mexico** (mr)
SUB: Fresnillo 60%

Pertusol a
ITALY

Pertusola Sud SA
DIR: Zn-Italy (r)
PAR: Metaleurop 51%

Phelps Oodge
USA

Phelps Dodge Corp
DIR: CU-USA (msr)
SUB: Morenci JV 85%, Chino JV 67%, SPCC 16%, Black Mountain 45%, Ojos **del Salado**

Pine Point
CANAOA

Pine Point Mines
PAR: Cominco 51%
SUB: Polaris JV 45%

Placer Dome
CANAOA

Placer Dome Inc
SUB: Marcopper 40%, Real de Angeles 33%

Polaris JV
CANAOA

Polaris Mine JV
DIR: Pb-Canada (m) Zn-Canada (m)
PAR: Cominco 55%, Pine Point 45%

Portland Smelter JV
AUSTRALIA

Portland Smelter Joint Venture
OIR: Al-Australia (s)
PAR: Alcoa of Australia 45%, State of Victoria Government 35%, First National Resource Trust 10%, China International Trust & Investment 10%

Preussag
FR GERMANY

Preussag AG
SUB: Metaleurop 51%, MIM 4%

Queensland Alumina
AUSTRALIA

Queensland Alumina Ltd
DIR: Al-Australia (r)
PAR: Comalco 30%, Kaiser 28%, Alcan 21%, Pechiney 20%

Raura
PERU

Cia Minera Raura SA
DIR: Pb-Peru (m) Zn-Peru (m)
PAR: Marmon 60%

RavensWood
USA
Ravenswood Aluminum Corp
DIR: Al-USA (s)
PAR: Stanwich Partners

Real des Angeles
MEXICO
Minera Real des Angeles
DIR: Pb-Hexico (m) Zn+lexico (m)
PAR: Friisco 33%, Placer Dome 33%, Government (Comision de Fomento Hinero) 33%

Red Dog JV
USA
Red Oog Mine Joint Venture
OIR: Pb-USA (m) pending Zn-USA (m) pending
PAR Cominco (Cominco Alaska) (development and operations). NANA (owns mineral rights)

Renison Goldfields
AUSTRALIA
Renison Goldfields Consolidated Ltd
DIR: Cu-Australia (m)
PAR: Cons Gold Fields 46%

Reynolds
USA
Reynolds Metals Co
DIR: Al-USA (rs), Canada (s)
SUB: Alcasa 28%, Aluminum Oxide Stade 50%, Becancour 25%, Halco 6%, MRN 5%, Valesul 1%, Worsley 50%, Valco 10%, Hamburg Aluminum 33%

Rio Algom
CANAOA
Rio Algom Ltd
PAR: RTZ 53%
SUE: Highland Valley 34%

Rio Tinto Minera
SPAIN
Rio Tinto Minera SA
OIR: Cu-Spain (sr)
PAR: RTZ 49%, Union Explosives 49%, Inversions Mobiliarias SA 2%

RMHK Trepca
YUGOSLAVIA
RMHK Trepca
DIR: Pb-Yugoslavia (msr) Zn-Yugoslavia (mr)
PAR: 6okernment

RTB Bor
YUGOSLAVIA
Rudarsko-TopiOnicarski -8asen Bor
OIR: Cu-Yugoslavia (msr)
PAR: Government

RTZ
UK
RTZ Corp Plc
SUB: Kennecott, Anglesey Alumina 51%, CRA 49%, Escondida 30%, Palabora 39%. Rio Algom 53%, Rio Tinto Hinera 49%, Norzink 50%, Somincor 49%, Greens Creek JV 53%, Tsumeb 14%

Ruhr Zink
FR GERHANY
Ruhr Zink Gmbh
DIR: Zn-FR Germany (r)
PAR: MG 50%, HIM 50%

Salzburger
AUSTRIA
Salzburger Aluminum GmbH
OIR: Al-Austria (s)
PAR: Alusuisse

San Ignacio Morococha
PERU
Cia Minera San Ignacio de Morococha SA
DIR: Zn-Peru (m)

Santander
PERU
Cia Minerales Santander *lnc*
OIR: Zn-Peru (m)
PAR: OocarbSA

Santo Toribio
PERU
Cia Hinera Santo Toribio SA
OIR: Pb-Peru (III) Zn-Peru (m)

shell
NETHERLANDS
Royal Outch/Shell Group
SU8: 8illiton

ShouaAluminum
JAPAN
Shoua Aluminum Industries KK
OIR: Al-Japan (r)
PAR: ShowaOenkaKK

SIEROMCO
SIERRA LEONE
Sierra Leone Ore & Metals Co
DIR: Al-Sierra Leone (m)
PAR: Alusuisse

Semincor
PORTUGAL
Sociedade Mineira de Neves Corvo SARL
OIR: Cu-Portugal (m)
PAR: RTZ 49%

Soral
NORWAY
SorNorge Aluminium A/S
OIR: Al-Norway (s)
PAR: Norsk Hydro 50%, Alusuisse 50%

Southwire
USA
Southwire Co
OIR: Al-USA **(S)** CU-USA (r)
SUB: Oubai Aluminum 8%, Cox Creek 20%

SPCC
USA
Southern Peru Copper Corp
OIR: Cu-Peru (ins)
PAR: Asarco 52%, Cerro Copper 21%, Phelps Oodge 16%, Newmont 11%
SUB: Cuajone JV 91%

Star-Phoenix Mining
USA
Star-Phoenix Mining
DIR: Pb-USA (m) Zn-USA (m)

Sumitomo
JAPAN
Sumitomo Metal Mining Co Ltd
OIR: Cu-Japan (sr) Pb-Japan (sr) Zn-Japan (r)
SUB: Morenci JV 15%, PASAR 10%, Akita Zinc 14%

Sumitomo Aluminum
JAPAN
Sumitomo Aluminum Smelting Co Ltd
OIR: Al-Japan (r)

Sunnyside JV
USA
Sunnyside Mine Joint Venture
OIR: Pb-USA (m) Zn-USA (m)
PAR: Alta Bay 65%, Washington Mining 35%

Sural
VENEZUELA
Suramericana de Aleaciones Laminados
SUB: Alusur 20%

Suralco
SURINAME
Suriname Aluminum Co
OIR: Al-Suriname (ins)
PAR: Alcoa
SUB: Suralco-Billiton JV **mine 24% & refinery 55%**

Suralco-Billiton JV
SURINAME
Suralco-Billiton Joint Venture
DIR: Al-Suriname (mr)
PAR: Onverdacht mine - Billiton 76%, Suralco 24%; Paranam refinery - Bill iton 45%, Suralco 55%

Tara Hines
IRELANO
Tara Mines Ltd
OIR: Pb-Ireland (m) Zn-Ireland (m)
PAR: Outukumpu 75%, Government 25%

Teck
CANAOA
Teck Corp
PAR: Metall Mining 10%, MIM 5%
SUB: Nunachiaq 50%, Highland Valley 14%, Afton JV 73%. Oaniel's Harbor JV 63%

Texas City
USA
Texas **City** Copper
OIR: **CU-USA (s) pending**
PAR: Mitsubishi 51%, 4 other Japanese companies

Toho Zinc
JAPAN
Toho Zinc Co Ltd
OIR: **Pb-Japan (sr) Zn-Japan (r)**
SUB: Akita Zinc 5%, Hachinohe 5%

Tomago
AUSTRALIA
Tomago Aluminium Co Pty Ltd
OIR: A1-Australla (s)
PAR: Gove 35%, Pechiney 35%, VAW 12% "

Touissit
MOROCCO
Cie Miniere de Touissit
DIR: Pb-Morocco (m)
PAR: Asturienne 50%, Government 20%, Matran 15%
SUB: Zellidja ?%

Trel1eborg
SWEDEN
Trelleborg AB
PAR: Edward & Peter Bronfman (Canada)
SUB: Boliden 68%, Falconbridge 50%

Tsumeb
NAMIBIA
Tsumeb Corp Ltd
DIR: Pb-Namibia (msr) Zn-Namibia (mr)
PAR: GFSA 76%, RTZ 14%

Union Explosives
SPAIN
Union Explosives Rio Tinto SA
SUB: Rio Tinto Minera 49%

Union Mines
USA
Union Mines Inc.
PAR: Acec-Union Miniere 93%, MHO 6%
SUB: Union Zinc

Union Zinc
USA
Union Zinc Inc.
DIR: Zn-USA (m)
PAR: Union Mines
SUB: Jersey Miniere

Valco
GHANA
Volta Aluminum Co Ltd
DIR: Al-Ghana (s)
PAR: Kaiser 90%, Ri ynolds 10%

Valesul
BRAZIL
Valesul Aluminio SA
DIR: Al-Brazil (s)
PAR: CVRD 55%, Bil" iton 45%, Reynolds 1%

Vana1co
USA
Vanalco Inc
DIR: Al-USA **(S)**
PAR: Bay Resources Corp

VAW
FR GERMANY
Vereingte Aluminium-Werke AG
DIR: A1-FR Germany (rs)
PAR: VIAG Aktiengesellschaft Bonn-Berlin (Government-Kreditanstalt fur Wiederaufbau) 60%
SUB: Aluminum Oxide Stade 50%, Halco 10%, Tomago 12%, Alouette ?%, Frialco 5%, Hamburg Aluminum 33%

Venal urn
VENEZUELA
Industria Venezolana de Aluminio
OIR: Al-Venezuela (s)
PAR: CVG 80%, Japanese Consortium 20%

Vexxal
VENEZUELA
Vexxal
DIR: Al-Venezuela (s) pending

Vieille-Montagne
BELGIUM
Ste des Mines et Fonderies de Zinc de la Vieille-Montagne SA
OIR: Pb-Sweden (m) Zn-8elgium (r), Sweden (m), France *(r)*
PAR: Acec-Union Miniere 96%

Volcan
PERU
Volcan Compania Minera SA
OIR: Pb-Peru (m) Zn-Peru (m)

Votarantim
BRAZIL
SA Industrial Votarantim
SUB: CMM, CBA 80%

Washington Mining
USA
Washington Mining
SUB: Sunnyside JV 35%

Western Mining
AUSTRALIA
Western Mining Corp Holdings Ltd
SUB: Alcoa of Australia 44%, Olympic Oam JV 51%

Westmin
CANADA
Westmin Resources Ltd
DIR: Pb-Canada (m) Zn-Canada (m)
PAR: Brascade Resources 62%

Woodcutters JV Australia	Woodcutters Mine Joint Venture Dill: Pb-Austral ia (m) Zn-Australia (m) PAR: Nicron 77%, Lachlan Resources NL 13%, Petrocarb Exploration NL 11%
World Bank USA	International Finance Corp SUB: Buenaventura 5%, Escondida 3%, PASAR 5%
Worsley AUSTRALIA	Worsley Alumina Pty Ltd DIR: Al-Australia (mr) PAR: Reynolds 50%, Billiton 38%, Kobe Alumina 10%
Young Poong **REP KOREA**	Young **Poong Mining Co Ltd** **DIR: Pb-Rep Korea (m) Zn -Rep Korea (mr)**
ZCA **USA**	**Zinc Corp of America** **DIR: Zn-USA (mr)** **PAR: Horsehead**
ZCCM ZAMBIA	Zambia Consolidated Copper M **nes Ltd** DIR: Cu-Zambia (msr) PAR: Government
Zellidja MOROCCO	Societe des Mines de Zellidja DIR: Pb-Morocco (sr) PAR: Touissit ?%
Zinc South Africa SOUTH AFRICA	Zinc Corp of South Africa DIR: Zn-South Africa (r) PAR: GFSA 65%

SOURCE: Office of Technology Assessment, 1990