LEAD-ZINC

2000

Edited by

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LEAD-ZINC 2000
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Proceedings of the Lead-Zinc 2000 Symposium which was part of the TMS Fall Extraction & Process Metallurgy Meeting, Pittsburgh, U.S.A., October 22-25, 2000

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PREFACE

The Lead-Zinc 2000 Symposium is the fourth in the series of decennial conferences on the processing of lead and zinc; it is organized by the Minerals, Metals and Materials Society (TMS) and is co-sponsored by the Australasian Institute of Mining and Metallurgy (AusIMM), the Canadian Institute of Mining, Metallurgy and Petroleum (CIM), the Gesellschaft für Bergbau, Metallurgie, Rohstoff-und Umwelttechnik (GDMB), the Institution of Mining and Metallurgy (IMM), the Mining and Materials Processing Institute of Japan (MMIJ), the International Lead Zinc Research Organization (ILZRO) and the International Zinc Association (IZA). The pioneering first decennial conference was held in St. Louis in 1970 and emphasized global operations in both the mining and processing sectors. The second conference, held in Las Vegas in 1980, reviewed both the practical and fundamental aspects of the production of lead, zinc, and also tin. The third meeting in Anaheim in 1990 discussed the theory and practice of the production of lead and zinc. As a reflection of the changing global situation of both metals, a significant part of the 1990 conference focused on secondary feeds and environmental considerations. The present Lead-Zinc 2000 Symposium builds on the foundations of those previous meetings, as well as on the achievements of similar events organized by the Canadian Institute of Mining, Metallurgy and Petroleum in Calgary, Canada in 1998, by the Mining and Materials Processing Institute of Japan in Sendai, Japan in 1995 and by the Australasian Institute of Mining and Metallurgy in Risdon, Australia in 1993. Like those previous international events, the Lead-Zinc 2000 Symposium brings together the world's processing, engineering and research communities to discuss the latest developments in the hydrometallurgical and pyrometallurgical processing of lead and zinc.

The Lead-Zinc 2000 Symposium will also honor Dr. T.R.A. Davey for his many contributions to metallurgical science and the industry throughout his distinguished career. The recognition of Dr. Davey at the Lead-Zinc 2000 Symposium is especially appropriate as he played a key role in the organization of the first decennial conference in 1970 and contributed to both the 1980 and 1990 meetings.

The proceedings volume of the Lead-Zinc 2000 Symposium is the culmination of over two years of work that included the preparation of the papers by the authors, as well as the refereeing, proof-reading and indexing by the editors. The proceedings volume contains sixty-four papers which cover all aspects of lead and zinc processing, including the global business trends of the metals, plant operations, new processing installations, emerging technologies and environmental considerations. The development of new and
improved smelting technologies continues because such processes can treat both primary and secondary feeds with the stabilization of many of the associated impurities in slag form. Innovative hydrometallurgical processes are being developed, and there is an on-going effort to integrate the best of both hydrometallurgy and pyrometallurgy into effective flowsheets which yield lead and zinc at low cost and in an environmentally friendly manner. Accordingly, it is the editors’ sincere hope that this proceedings volume will remain a valuable record of the Lead-Zinc 2000 Symposium and that it will become a standard reference for the processing of lead and zinc.

The production of this proceedings volume was a major undertaking, and many individuals were involved over the course of several months. Accordingly, the editors would like to extend their sincere appreciation to Dave Hardy, Marilyn Harris, Lorna Paquette and Hariranja Rakotoarimanga at CANMET, and to Dan Ashman, Lida Gambin and Juris Harlamovs at Cominco Research. The editors genuinely appreciate their assistance with the refereeing and/or editing of the various papers, and we thank them for their assistance in the production of the proceedings volume of the Lead-Zinc 2000 Symposium.

Pittsburgh
October 2000

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EDITORS' BIOGRAPHIES

John E. Dutrizac attended the University of Toronto where he received his B.A.Sc. degree in metallurgical engineering in 1963 and his Ph.D. degree in 1967. Upon graduation, he worked for a short time at the Noranda Technology Centre in Pointe Claire, Québec. In 1968, he joined CANMET as a Research Scientist, and began to study a variety of hydrometallurgical problems. His current research activities are centred on zinc processing with its associated iron precipitation problems, the leaching of sulphide minerals, and the characterization of the anodes and anode slimes encountered in copper electrorefining. These efforts commonly involve the integration of chemical metallurgy with the techniques of applied mineralogy to improve the understanding of the process. Dr. Dutrizac has over two hundred publications in these and in related fields. John Dutrizac is a former Chairman of the Hydrometallurgy Section, and a Past President of the Metallurgical Society of CIM. He has received many international awards, and is a Fellow of the Chemical Institute of Canada and the Canadian Institute of Mining, Metallurgy and Petroleum.

Jose Alberto Gonzalez was born in Mexico City in 1960. He received B.Sc. and M.Sc. Degrees in Metallurgy from the University of Mexico (UNAM) in 1984 and 1985, respectively. He then pursued Ph.D. studies at the University of British Columbia (UBC) in the area of lead electrorefining, under the supervision of Prof. Ernest Peters. After the completion of his Ph.D. degree he joined Cominco in 1991, where he is currently Principal Research Scientist and heads the Electrometallurgy Section in Cominco Research. Since 1997, he has been on the editorial board of the Hydrometallurgy Journal. In 1994, he became an Adjunct Professor at UBC where he has been involved in Electrometallurgy and Hydrometallurgy Chair research activities. His research focuses on developing energy efficient ways to electrowin zinc and copper and on optimizing the winning and refining of lead from fluosilicate electrolytes.

Daniel M. Henke grew up in Wyoming, U.S.A. and attended college at the South Dakota School of Mines and Technology in Rapid City, South Dakota. Daniel earned a B. Sc. degree in Metallurgical Engineering in 1979. Upon graduation, he joined St. Joe Minerals at the primary lead facility in Herculaneum, Missouri. In 1986, St. Joe Minerals became the Doe Run Company. The many positions he has held over the past 21 years with the Doe Run Company include: Assistant Superintendent Blast Furnaces, Superintendent Blast Furnaces, Superintendent Refinery, Production Manager, Facility Manager. His current position is Operations Manager of the products and technical service departments. The managerial responsibilities of the products area include the refining,
alloying, and casting of the lead products, shipping of all the finished goods, and production of lead strip and sheet products. The responsibilities of the technical services group include supporting customer service, directing all quality programs, and supporting other operational processes.

Steven E. James has worked for over 20 years in the United States zinc industry at three different operating plants. A graduate of the Colorado School of Mines in Metallurgical Engineering, he began his career as a Research Engineer for the St. Joe Minerals Corporation in Monaca, Pennsylvania. Among other activities, Steve served as the key process engineer for a lead hydrometallurgical pilot plant during a successful 2-year operation. After organizing and leading the hydrometallurgy research group for St. Joe Minerals, he assumed a position as a process engineer at the National Zinc Division of St. Joe Resources Co. in Bartlesville, Oklahoma. He served in a variety of operating positions there, eventually becoming production manager for the electrolytic zinc plant under its new owners, The Zinc Corporation of America. Zinc production and worker safety improved every year during his tenure as production manager. In 1991, Steve joined the Big River Zinc Corporation in Sauget, Illinois as the Director of Technology, a role he still fills. Steve is a member of The Minerals, Metals and Materials Society, The Mining History Association, The Canadian Institute of Mining, Metallurgy and Petroleum, The North American Zinc Processors, and The American Society for Quality. He is both a past chairman and incoming chairman of the Lead-Zinc-Tin Committee of The Minerals, Metals and Materials Society.

Andreas H.-J. Siegmund was born and raised in Hanau, Germany. After graduation from high school in Hanau, he enrolled in metallurgical engineering at the Technical University of Berlin, Germany where he received the degree of Dipl.-Ing. in 1985. He then worked in the laboratory of Preussag AG in Goslar, Germany in a joint research project between Preussag AG and the Technical University of Berlin. In 1989, he received the degree of Dr.-Ing. from the Technical University of Berlin for work in the area of the electrorefining of ultra-pure cadmium. After completion of his Doctoral degree, he joined Lurgi Metallurgie GmbH were he was involved in the commissioning of all QSL plants for lead smelting, and progressed through various responsibilities to Head of the Nonferrous Process Department. Since 1998, he is Manager Research and Development at RSR Technologies, Inc. in Dallas, Texas focussing on projects for lead recovery from secondary and primary sources and working with anodes for Cu- and Zn-electrowinning. He is an active member of the Lead Committee of the GDMB and is currently Chairman of the Pb-Zn Committee of TMS.
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Chapter 1

Global Factors Affecting Lead and Zinc
MARKET FUNDAMENTALS AND THE EVOLUTION OF LEAD AND ZINC SUPPLIES

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ABSTRACT

The opening years of the new millennium will be characterised by the closure of many lead and zinc mines because of reserve depletion. However, weak commodity prices through the second half of the 1990s have slowed project evaluation and have made it difficult to raise finances for the development of new mines required to replace lost output and to meet increasing demand for metal in the future. Growth of lead and zinc demand will be determined by the pace of global economic activity, especially in the emerging economies. How rapidly demand grows will have a key bearing on the possible shortfall in mine output and the response of prices to the implied tightening of metal supplies early in the new millennium. These issues are the focus of a discussion of the critical lead and zinc supply developments which will unfold post 2000, taking into account project lead times and the role that recycled metal plays in meeting market demand.
LEAD AND ZINC SUPPLIES

In this paper we will examine the evolution of lead and zinc supplies, the market factors influencing these supplies and will then seek to draw some conclusions from this analysis about future prospects for both industries.

In looking at the evolution of supply, we take into account the natural links between the lead and zinc industries, which are determined by the fact that their respective minerals are often found and exploited together. We shall also examine those developments that have made this natural linkage far less important today than was the case 30 or 40 years ago.

First of all, we need to clarify some definitions. With the collapse of communism in Eastern Europe and the Soviet Union and the opening up of China, there is a clear need now to look at developments in the lead and zinc industries in global terms; i.e., including every country in the world. However, in looking at historic development trends, one encounters the problem of consistency and accuracy of reporting in the former communist countries, particularly the Soviet Union, as well as continuing problems in the collection and collation of data in some of these countries and in China. For this reason, we continue to make the distinction between the “transitional” economies, which we define as China, North Korea, Vietnam, Cuba, the Former Soviet Union (FSU) and the Warsaw Pact countries of Eastern Europe, and the Western World which comprises all other countries. Much of the subsequent discussion refers solely to the Western World but, where possible, we also quote global numbers and/or numbers for the transitional economies.

As shown in Figure 1, in 1960 Western World production of lead and zinc was 2.5 Mt and 2.4 Mt, respectively. Based on average prices in that year, the output of the lead and zinc industries together was worth a little over $5 billion in today’s terms. Unfortunately, we do not have very reliable figures for lead and zinc production in the transitional economies of 40 years ago. The best estimates are those produced by the International Lead and Zinc Study group that show that “socialist” countries produced 0.72 Mt each of lead and zinc. (Following the break-up of the Soviet Union it became apparent that lead and zinc production may well have been over-stated in the USSR, but it is still difficult to determine what output might have been as long ago as 1960.) If we accept these numbers, then this implies that the output of the global lead and zinc industries in 1960 was worth around $6.8 billion.
Returning again to a discussion limited to the Western World, it is worth noting that, in 1960, the value of lead and zinc output taken together accounted for 18% of total non-ferrous production (Al, Cu Pb, Zn, Sn and Ni), with zinc’s share standing at 10% and lead’s at 8%. How have matters changed? In the last year of the 20th Century, Western World lead production was 4.9 Mt and zinc 5.8 Mt. Now that we have much greater faith in the data flowing from the transitional economies, we estimate that global production of lead and zinc in 1999 was 6.2 Mt and 8 Mt, respectively. Compared with 40 years ago these totals are 93% higher for lead and 153% higher for zinc. Turning again, for a moment, to consider just the Western World, the value of zinc output in 1999 was 120% higher in real terms compared with 1960. For lead the increase was only 5%. Overall their combined share of Western World non-ferrous output was a little smaller than in 1960 at just over 16%. However, zinc increased its share of the total to nearly 12% while lead saw its share fall to only 4.5%.

Clearly much has changed, therefore, in the relative positions of these two metals over 40 years, both in terms of the balance between lead and zinc output and the position of these metals in the global non-ferrous industry. What have been the fundamental issues affecting the demand for these metals which have had such a significant impact on their relative performance, both in terms of output growth and the actual value of production?

For all metals, the most important determinant of demand growth is the pace of economic activity. Usually a measure of industrial production is taken as the most appropriate indicator of this when looking at metal demand. The second factor to examine is the intensity of metal use. In other words how many tonnes of metal are consumed for each unit of industrial output? This key element in determining metal demand reflects, in broad terms, the uses to which a metal is put. The intensity of use value varies from country to country depending on the structure of industrial output. It also varies over time as individual economies pass through different stages of industrialisation and development and increasing per capita
incomes, leading finally to a stage where the service sector becomes the main area of increases in economic activity. In addition, intensity of use is affected by substitution of one material for another, changes in design of products and, increasingly important at the end of the 20th Century, environmental concerns.

Looking first at lead demand we can see that there have been huge changes in the end-use patterns of consumption over the past 40 years. In 1960 lead-acid batteries accounted for a little under 30% of all uses. Rolled products (lead sheet and pipe and ammunition) had a 21% share of the market and cable sheathing was another major end use with an 18% share. Lead also found significant applications in chemicals (pigments, oxides and tetra-ethyl lead) and alloys. At the end of the century batteries had come to dominate all other end uses, accounting for almost three-quarters of all consumption. Use in pigments and compounds had a 10% share while rolled products represented only 8% of the market. All other uses were relatively insignificant.

This dramatic change in the market for lead had one over-riding cause. This was the appreciation of lead's toxicity in the general environment and, in particular, the effect of exposure to lead on children's mental development. This meant that all uses of lead came under very close scrutiny with many countries taking decisions to restrict severely the use of lead in applications such as paints, pipes, alloys and chemicals, including tetra-ethyl lead used as an additive in gasoline. Thus, while one end use, the requirement for lead in batteries, has seen a significant increase in absolute levels of consumption, reflecting the ever-increasing number of vehicles on the roads and the growing market for industrial batteries, the demand for lead in virtually all other applications has fallen. In fact, the apparently poor performance of lead consumption growth, especially in more recent years, masks very impressive growth in demand for lead in batteries. Over the past 15 years annual consumption growth in batteries has averaged a very respectable 3.9%. This contrasts with only a 2% per annum value for total consumption. In absolute terms there was a 350 kt decline in Western World offtake for all non-battery application between 1984 and 1999. Over the same period, lead use in batteries grew by more than 1.75 Mt. Further significant demand growth in lead use in batteries can be expected for the foreseeable future. While the pace of growth in vehicle fleets has slowed in the mature economies, a large number of new cars, trucks and buses are being added each year to the total of vehicles on the road in the emerging and transitional economies. Furthermore, the infrastructure required to support the rapid spread of mobile telecommunications and the need for back-up power supply systems for electronic equipment everywhere have created important growth markets for lead-acid industrial batteries. The likely increase in lead offtake will have to be met principally from primary sources, in other words, from mine production.

For zinc there have also been some important shifts in the patterns of consumption, but these have not been as significant as for lead. However, it is the case that most of the growth in demand has occurred in one end use. In common with lead, environmental factors have also played a major role in determining the use of zinc in some applications. However, the issue was not toxicity, but rather weight. In the 1960s and early 1970s many components in cars were made from zinc die-castings. These included some structural elements as well as parts such as carburettors and exhaust manifolds. The first oil crisis of 1973-1974 forced automakers to redesign their vehicles to improve fuel efficiency. Reducing the weight of cars was an important step in this process. As a result there was great incentive to re-engineer parts and to substitute heavier metals by lighter metals (aluminium for zinc) and plastics. The die-casting industry responded to this threat by introducing new technology to produce lighter components and developed thin-wall die-casting. While this meant that zinc continued to be used for some parts in cars, the per-unit use of zinc fell. Also this same technology found applications outside of the auto industry, causing a further erosion of zinc offtake. Overall, as a result of direct
substitution and the use of thin-wall die-casting techniques, zinc consumption in this single application has still to regain the levels achieved in 1973.

Another end-use, which has suffered because of weight considerations in the auto industry and substitution by plastics, has been the use of zinc in brass. While the impact of these developments was not as severe as in the case of die-casting, it was not until 1994 that the consumption of brass surpassed the levels first reached in 1973.

Zinc's major end use, galvanising, has seen its Western World market share increase from just under a third of all consumption in 1960 to around 50% today. Somewhat ironically a significant boost to the use of galvanised sheet came from the auto industry. Pressure from consumers and competition to produce a better product forced the auto companies to adopt the widespread use of galvanised sheet in the construction of cars in order to offer warranties against corrosion. This was especially evident in the growth of zinc demand in the 1980s in the USA and Japan and in the late 1980s/early 1990s in Europe. In many of the emerging economies carmakers have yet to switch to the extensive use of galvanised sheet. This will happen in due course and will provide further gains for zinc demand. Although much attention has focussed on the use of galvanised sheet in the auto industry, it is construction that actually consumes more zinc, not just in galvanised products, but also in the form of brass and zinc sheet. This latter product is particularly important in mainland Europe as a roofing and cladding material. In addition, zinc-coated sheet finds many applications in general construction where it is used as sacrificial shuttering for concrete floors, cable trays, air conditioning ducting, etc. It is these uses that have been responsible for the strong consumption growth rates for zinc that were evident in Asia for much of the 1990s.

Western World growth in zinc consumption in galvanising over the past fifteen years has amounted to 1.7 Mt representing an annual average rate of increase of almost 4%. All other uses together have increased by 0.7 Mt at an annual average growth rate of 1.4%. Thus, in common with lead, growth in zinc demand has largely reflected gains in a single end use. However, in the case of zinc, this single major application accounts for about 50% of total zinc demand and all other applications are still exhibiting some growth, albeit relatively slow in some instances. For the foreseeable future galvanising will remain the principal area of demand growth for zinc, with the best performance almost certainly to be in the emerging/maturing economies, especially in Asia. Infrastructure and other construction activity will underpin these growing markets for zinc.

Before we can consider how the market fundamentals have affected the evolution of lead and zinc supplies, there are a number of other aspects of the market equation that need to be considered. One factor that has played a critical role in determining the characteristics of lead supplies has been the increasing availability and recycling of lead scrap and the treatment of other secondary materials to produce refined lead. Lead is unusual amongst the non-ferrous metals in that the life cycle of the product in which it finds its principal end use is rather short (typically 2 to 6 years for SLI batteries and 6 to 8 years for industrial batteries). Furthermore, batteries contain the metal well and can be collected relatively easily at the end of their useful lives. Finally, there is almost no dissipation of the lead used in batteries during normal working conditions. These factors taken together mean that lead has the highest rate of recycling of any metal. Losses reflect the rather small proportion of batteries not recycled and the inevitable loss of some lead during processing.

Given that the share of the market for lead accounted for by batteries has been increasing steadily, it is no surprise that an increasing proportion of lead supply has been met from secondary sources. Fifteen years ago, secondary sources accounted for only 48% of
Western World lead production. By 1999 this share had increased to over 61%. Perhaps more strikingly, Western World secondary output has grown at an average annual rate of 2.8% since 1984. Primary output (from lead and bulk concentrates) has barely risen at all. We should note that, in our calculation of secondary production, we are including the treatment of secondary materials in “primary” smelters as well as production at dedicated secondary operations. Although it has always been the case that some residues from other metallurgical plants and industrial wastes have been processed in primary smelters, there has been a sharp increase in the volume of non-concentrate feed processed by the primary sector in recent years. The initial spur to this was an acute shortfall in lead concentrates in the years 1993/1994. However, tighter environmental legislation introduced during the 1990s also meant that more lead-containing industrial wastes were offered to lead smelters as a cheaper option to expensive land fill, and the opening up of the Eastern European economies and the former Soviet Union exposed a legacy of waste materials which could be treated economically by lead smelting operations in the West.

The fact that the lead market is now so dependent upon secondary materials to meet demand, with the bulk of scrap derived from batteries, means that there ought to be a self-regulating mechanism to balance lead supplies against demand. If demand is growing strongly, this suggests that sales of replacement batteries are buoyant. And for each replacement battery sold a battery is scrapped. So long as the recycling chain is efficient (which it now is in most mature economies although it is still susceptible, to a degree, to price pressures), growth in replacement battery sales should also be accompanied by an increase in secondary production. The reverse situation should also be true with a sluggish battery market leading to a tightening in scrap supplies. While this theory is fine and could, perhaps, have been seen operating during the second half of the 1980s, developments in the 1990s have upset all earlier assumptions. Figure 2 above shows that there was an absolute decline in secondary refining in the early 1990s and again towards the end of the decade. It is probable that low lead prices played a major role in this. When prices recovered in the mid-1990s, so too did the availability of lead scrap, though weak prices in recent years have again caused the volume of scrap collected to fall. However, a more critical factor has been at work in causing the breakdown in the theoretical natural balance between supply and demand that was seen emerging in the West during the 1980s, as batteries became the dominant end use of lead. This was the sudden appearance of new supplies of primary lead in the early 1990s with exports to the West from the FSU and Eastern Europe and, in more recent years, from China.
Before discussing further the impact of the break-up of the Soviet Union and the emergence of China as a force in the lead and zinc industries, we need to consider also the role of secondary production in zinc output. Unlike lead, most of the products using zinc have a relatively long life cycle and, in some cases, the zinc used tends to dissipate over the product’s useful life. Even where the zinc remains in situ, its economic recovery may be difficult. There has been much attention given to recovering the zinc used to galvanise steel. Where zinc coated steel scrap is smelted in an electric arc furnace, the dust captured is increasingly being treated and the zinc recovered. EAF dust is formally classified as a hazardous waste in much of the world today, but whether it is recycled or not depends on a range of factors, including the relative costs of recycling versus the alternatives (if permitted) of hazardous waste disposal at an approved site and/or stabilisation in a manner that complies with national standards. Some EAF dust is taken directly into the zinc smelting industry (with, for instance, some Imperial Smelting furnaces using such material directly) but the majority is pre-treated, typically though not exclusively in Waelz kilns, before being sold as a crude zinc oxide to both ISFs and to electrolytic smelters. It is expected that EAF dust will become a much more significant source of zinc-containing feed for the zinc smelting industry in the future, a direct result of a higher proportion of zinc in the steel scrap as more intensively galvanised autos are themselves scrapped. However, zinc produced from secondary sources will remain a relatively small part of overall supply, even though there will continue to be an increase in the rate of recovery.

So far we have described some key characteristics of the lead and zinc markets. Traditionally the two metals have been mined together. Zinc demand has grown at an overall faster rate than lead in recent years. Lead consumption is dominated by a single end use which, in turn, currently depends largely on a single end-use sector, vehicles; other end uses for lead are contracting. Zinc also has a major end-use, galvanising, but it is by no means the only end use and demand for its other applications is also growing albeit quite slowly; galvanised steel is used in a wide variety of final end uses. Lead and bulk concentrates in the West now account
for less than 40% of total lead feed. Secondary output of zinc, although it is growing, remains a relatively small part of overall supply, with zinc and bulk concentrates still accounting for just over 90% of total zinc feed units.

Although we have focussed on developments in the Western World in making our comparisons of the factors that characterise the lead and zinc industries, the situation today is that we have a global market for all commodities, as is suggested by Figure 3. Much has been written about the impact on metal markets of the break-up of the Soviet Union and the integration of China into the world's trading system. In essence, for lead and zinc, the principal shock to the "system" was a sudden and unexpected increase in supply coming into the market, apparently at the bottom end of the cost curve. Certainly for operations in the former Soviet Union (mainly Kazakhstan) the physical assets (mines and smelters) were transferred to new owners at almost no cost and these operations were then subjected to a form of asset stripping for a number of years. In the case of a number of mines that have now closed, previously developed ore was extracted but the very low grades at these operations meant that no one was prepared to make any further investments. For the smelters little was spent on maintenance for a number of years but, more recently, this situation has changed and we are now seeing a recovery in output of both metals in the FSU. This has not, so far, been matched any meaningful rise in domestic consumption.

![Figure 3 - Net East/West Trade in Refined Lead and Zinc](Source: ILZSG, CHR Metals)

China's entry into the world of lead and zinc could not have been more different from the circumstances in the other countries in the former Eastern Bloc. Prior to the mid-1980s China's refined lead production was no more than 225 kt/a and zinc output was around 300 kt/a. From the mid-1980s, however, there was a sharp increase in mine production of both metals that, initially, was much greater than the rise in refined output. The development of new mines was the direct result of official policy to promote the domestic lead and zinc industries to