The Future Supply of the Major Metals

A Reconnaissance Survey

By BRUCE C. NETSCHERT
and HANS H. LANDSBERG

RFF

RESOURCES FOR THE FUTURE, INC.

Lead and Zinc

The usual difficulties in the quantitative and qualitative assessment of the reserves and resources of a metal are intensified for lead and zinc because of the nature of their occurrence. Although deposits do occur in which zinc is unaccompanied by lead, or vice versa, the usual occurrence of these metals is in deposits of lead and zinc minerals in association. In addition, lead and zinc occur with a wide variety of accessory metals and minerals, such as copper, gold, silver, antimony, bismuth, cadmium, and pyrite (valuable for its sulfur in some parts of the world). Indeed, lead and zinc are so frequently co-products or by-products that the term "grade" in lead-zinc mining is often expressed as the value of the combined content of all metals rather than as the content of lead or zinc alone. The significance of the lead or zinc content by itself is thus drastically reduced; and by the same token, it is not possible to delimit reserves from potential ore on the basis of such content except at the most general level.

Deposits in which lead and zinc are the predominant metals are frequently small and highly irregular in shape. They must be mined by a variety of underground methods, many of which are not suitable for use on the scale of mining commonly used for the metals discussed previously. This does not mean that unit costs in lead-zinc mining are necessarily high (the metals are, if anything, remarkable for their relative cheapness); it does mean, however, mines of smaller capacity, on the average, than those producing iron, manganese, aluminum, and copper. These same physical characteristics of the lead-zinc deposits also tend to require higher capital outlays per unit in the development of reserves; the life index of lead and zinc reserves is therefore small compared with those of the preceding metals, and the usefulness of the reserve data for present purposes is thereby much reduced.

Because of the common association of the two metals the following discussion differs in organization from the preceding sections. The reserve-resource position and supply versus demand comparisons are examined separately for each; the cost implications are considered jointly.

itative assessment of
:d for lead and zinc
;h deposits do occur
rsa, the usual occur-
minerals in associa-
variety of accessory
antimony, bismuth,
parts of the world).
. or by-products that
›ressed as the value
s the content of lead
nc content by itself
n, it is not possible
: such content except

inant metals are fre-
must be mined by a
: not suitable for use
ıetals discussed pre-
inc mining are neces-
›le for their relative
ller capacity, on the
ıminum, and copper.
ıc deposits also tend
development of re-
therefore small com-
usefulness of the re-
ıced.
tals the following dis-
ections. The reserve-
arisons are examined
idered jointly.

LEAD

Domestic Reserve-Resource Position

The current official estimate of United States lead reserves is 2.9 million short tons in the measured and indicated categories plus about 2.7 million tons inferred, or 5.6 million tons, total. Of this, between 70 and 80 per cent is considered recoverable with current technology at present prices.[1]

Although lead is produced as a co-product or by-product from ore with less than 1 per cent lead content, the U.S. Geological Survey and Bureau of Mines in their report to the PMPC noted that identified potential lead ore may carry as much as 7 per cent lead. This illustrates the fact, referred to above, that the value of the other metals and minerals present is more important than the percentage of lead alone as a cost determinant. Material in one deposit with a lead content seven times that in another may nevertheless be uneconomic, for a variety of reasons. The agencies estimated that the total lead content of identified potential ore was no greater than the reserve figure at that time, or some 8 million tons.[2]

The contrast between these figures and the estimates for the metals previously considered is startling. For each of the other metals, identified potential ore is at least several times the reserve level; for lead, identified potential ore is not much more than reserves. This anomaly, which is of crucial significance in assessing the future supply position, is considered further below.

Domestic Supply Versus Demand

In the comparison of projected requirements with identified reserves and resources in Figure 9 it is apparent that discoveries of many new districts, not merely extensions of measured and indicated reserves in known districts, would be required if annual domestic mine production

[1] U.S. Bureau of Mines, *Mineral Facts and Problems, 1960 edition* (Washington: U.S. Government Printing Office, 1960), p. 436. This recovery takes into account all losses from mining through production of refined metal. The discussion of copper recovery above, it should be noted, refers to milling losses only. In other stages of production, losses of copper are negligible compared with losses of lead and zinc.

[2] The President's Materials Policy Commission (PMPC), *Resources for Freedom* (Washington: U.S. Government Printing Office, 1952), Vol. II, p. 151.

were to do no more than hold the average of the past five years (roughly 300,000 tons) during the remainder of the century. Domestic self-sufficiency in the future would appear to be beyond any conceivable possibility. In the period 1954-59 domestic mine output amounted to a little over one-quarter of primary lead consumption, on the average, compared with one-third in the period 1949-53, despite an absolute decline in consumption. Mine production in 1960 of 239,000 tons was roughly one-third that of the peak production years in the 1920's, when output approached 700,000 tons; even with governmental stimuli the production peak during World War II was less than 500,000 tons and during the Korean War less than 400,000 tons. In our opinion, this constitutes abundant evidence that resource depletion is the dominant reason for the industry's decline.[8]

Such evidence led S. G. Lasky, as well as the PMPC, to conclude that primary lead production in the United States would probably continue to decline in the future.[4] Large improvement in recovery, while helpful, would not change the situation fundamentally. There is no reason to disagree with this conclusion, barring a drastic improvement in the ability to discover new lead districts. The maintenance of an average annual output of 300,000 tons over the period 1960-2000 would mean cumulative production of 12 million tons and the necessity of finding, at the very least, additional reserves equal to twice current reserves, or roughly the equivalent of total currently identified resources. Even an annual level of 100,000 tons would require the discovery of more reserves than are currently identified, but this could be accomplished if the rate of additions to reserves in the 12 years, 1944-56, were to be maintained.[5]

[8] This allows for the recurrent strikes that have plagued the industry in recent years and contributed to a low level of output. The fact that many mines have closed because of price competition from foreign sources is not evidence against resource depletion but on the contrary further supports the argument. In former years the U.S. industry provided the price competition which foreign sources had to meet.

[4] PMPC, *op. cit.*, Vol. II, p. 41.; S. G. Lasky, "Mineral Industry Futures Can Be Predicted—II," *Engineering and Mining Journal*, September 1955, pp. 94-96.

[5] Estimated reserves as of 1944 were 7.75 million tons (U.S. Bureau of Mines and U.S. Geological Survey, *Mineral Resources of the United States*, Washington, Public Affairs Press, 1948, p. 126). Production from 1945 through 1956 totaled 4.5 million tons, with 5.6 million tons of reserves estimated at the end of the period. Gross additions to reserves thus totaled 2.35 million tons in the 12-year period. At this rate, reserve additions in the next 40 years would total 7.5 million tons.

ars (roughly
ɔmestic self-
ceivable pos-
ɿounted to a
the average,
an absolute
000 tons was
1920's, when
ɿl stimuli the
000 tons and
opinion, this
the dominant

', to conclude
probably con-
ɜcovery, while
There is no
: improvement
tenance of an
50-2000 would
ɜcessity of find-
.ce current re-
ified resources.
ɿe discovery of
ɿuld be accom-
1944-56, were

industry in recent
many mines have
t evidence against
ument. In former
ɔreign sources had

ustry Futures Can
1955, pp. 94-96.
. Bureau of Mines
States, Washington,
ɔugh 1956 totaled
at the end of the
ons in the 12-year
's would total 7.5

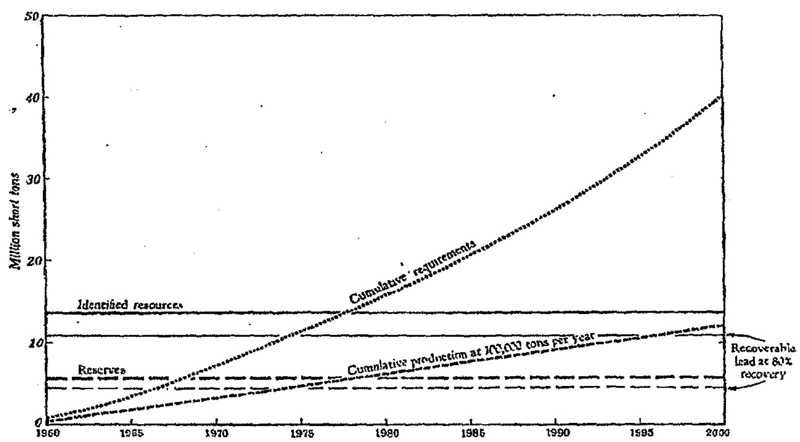

FIGURE 9. *U.S. primary lead requirements, 1960-2000, compared with the contained lead in domestic reserves and domestic identified resources*

Recent developments in Missouri may require modification of these conclusions. The Viburnum deposit, discovered in 1956, and subsequent other unrelated discoveries in the same area are rumored to be of the first magnitude. In view of the unfortunate secrecy surrounding the details of these discoveries their significance for future domestic primary lead supply cannot be assessed publicly. At worst, some of the needed additions to reserves referred to above have already been made. At best, the new discoveries may be sufficiently large to more than offset the decline in productive capacity elsewhere in the United States and restore annual mine output to 300,000 tons or more. What these discoveries indicate is that there *are* more sizable lead deposits awaiting discovery in this country. It remains to be seen whether these discoveries can be considered evidence of the drastic improvement in discovery ability referred to in the preceding paragraph as the only factor that might forestall declining production.

Foreign Reserve-Resource Position

Foreign lead reserves in the measured and indicated categories only are given in Table 8 and total 45.9 million short tons. The figure for

Asia is stated in the source to include Burma, China, India, Iran, and Japan, but elsewhere, the lead reserves of China alone have been reported to be from 3 to 6 million tons.[6] The Asian figure and the foreign total are both certainly minimal.

The Bureau of Mines states that "the reserve of inferred ore is probably as much or more,"[7] but in the absence of any data this is merely

TABLE 8. LEAD: FOREIGN RESERVES, MEASURED AND INDICATED, 1957

	Thousand short tons metal content
North America:	11,700
Canada	8,000
Mexico	3,500
South America:	2,500
Europe:	13,700
West	9,100
East	4,600
Africa	3,500
Asia	2,000
Australia	12,500
Total	45,900

Source: U. S. Bureau of Mines, *Minerals Yearbook, 1957* (Washington: U. S. Government Printing Office, 1958), Vol. I, p. 725.

a more or less informed guess. A somewhat more specific guess was made previously in 1955 by a Bureau of Mines specialist who suggested on the basis of the partial information at hand that the total reserves of the world in all three categories might be something like 100-150

[6] K. P. Wang, *Rich Mineral Resources Spur Communist China's Bid for Industrial Power* (Special Supplement No. 59, *Mineral Trade Notes*) (U.S. Bureau of Mines, March 1960), p. 30.

[7] U.S. Bureau of Mines, *Minerals Yearbook, 1957* (Washington: U.S. Government Printing Office, 1958), Vol. I, p. 725.

million tons of lead.[8] Inferred reserves, in other words, may be two to three times as much as the other two categories combined. In any event, because of the general lack of data in the inferred category, further speculation concerning the size of potential ore resources was considered fruitless in the report of the PMPC.[9] Opinion on this point would seem to be unanimous, for as far as we know there are no world estimates of potential ore anywhere.

World Supply Versus Demand

In Figure 10 the line for estimated reserves is solid through 50 million tons, the approximate total of the measured and indicated categories, and becomes increasingly broken beyond this to the 150 million-ton point, in recognition of the highly probable existence of some inferred reserves and the increasingly hypothetical nature of larger tonnages included in the speculation of up to 150 million tons total reserves.

Quantity C at 176 million tons represents cumulative world demand between 1960 and 2000 at an average growth rate of 2.7 per cent, the same that prevailed between 1950 and 1960. Quantity B at 139 million tons represents a rate of 1.6 per cent, which prevailed between 1955 and 1960. Quantity A, at approximately 100 million tons, represents a continuation of the 1960 consumption level through 2000.

The rate of growth in world primary lead consumption has clearly been declining and again the United States appears to be leading the way. In this country primary lead consumption over the past decade has undergone an absolute decline, due both to an increase in secondary supply and to substitution away from lead. This decline amounted to almost 25 per cent over the decade as a whole and 17 per cent in the last half of the decade. Thus it is likely, barring unforeseen developments in the demand pattern for primary lead, that the growth rate in world demand through the remainder of the century will be closer to Quantity B than Quantity C in Figure 10.

Even if there were no growth in demand at all, however, it is apparent that large discoveries of lead are needed. Figure 10 shows the total lead

[8] O. M. Bishop, "The Reserve Base for the World's Lead-Zinc Industries," paper presented at meeting of the American Zinc Institute and Lead Industries Association, Chicago, April 28, 1955.

[9] PMPC, *op. cit.*, Vol. II, p. 151.

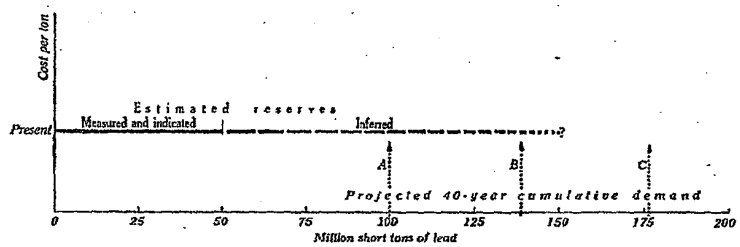

FIGURE 10. *Adequacy and cost implications of projected world demand for lead*

contained in ore; allowing for 80 per cent recovery, measured and indicated reserves of recoverable lead are only 40 million tons, and the equivalent ore requirement for each possible cumulative demand is 20 per cent greater. Given the undoubted understatement in the measured and indicated reserve data and the "discoveries" that will be made from the inferred category, considerable additions can be made to reserves. The outlook concerning true discovery of new ore bodies and districts, however, is less sanguine. The report of the PMPC, after a survey of the general occurrence of lead and the postwar discovery record, concluded that "the outlook for the discovery of substantial new reserves . . . [was] not encouraging."[10] Whether or not this judgment is correct, until there is clear evidence to the contrary the adequacy of future additions to reserves as presently defined remains questionable.

This directs one's attention to the resource situation and the level of identified potential ore, so as to get some idea of possible cost effects in the event of inadequate discoveries of additional reserves (defined according to present criteria, it should be remembered). But Figure 10 contains no representation of resources, for there is nothing to represent. The only figure available, the 8-million-ton estimate of United States potential ore, is too small to warrant separate identification.

Yet the potential ore figure for the United States raises a question of great interest. If the small ratio of potential ore to reserves represents the true concentration distribution of lead in nature, then the potential ore available in the world as a whole is also comparatively small in

[10] PMPC, *op. cit.*, Vol. II, p. 43.

quantity. And if the unoptimistic discovery outlook indicated in the report of the PMPC is also correct, the world might experience a sharp rise in the price of lead even before the end of this century.

It was observed above that in the case of lead the ratio between potential ore and reserves is unusually small. If this reflects natural circumstances, lead is an anomaly in this respect which should have provoked the attention of the geological profession before now. If it does not reflect natural circumstances it must be that, for reasons peculiar to the lead mining industry, little attention has been given to the identification and quantitative estimation of occurrences of potential lead ore. The presentation of the 8-million-ton potential ore figure by the U.S. Geological Survey in the PMPC report is of no help in this respect, for it does not point out either an anomalous potential ore-reserve ratio or a serious quantitative underestimation of what actually exists in nature. This point is discussed further below.

ZINC

Domestic Reserve-Resource Position

In 1957, the U.S. Bureau of Mines estimated measured and indicated reserves of zinc in the United States to be 13,485,000 short tons of metal in ore. As is true for lead, between 70 and 80 per cent is currently recoverable.[11] Inferred reserves "are judged to be at least equal to the sum of measured and indicated reserves."[12] A summary of the reserve position, as of 1950, showed 12.7 million tons of inferred reserves. This was the result of a reappraisal of postwar data on half of the "66 considered districts that are believed to contain the major domestic reserves." It does not include, however, inferred reserves "in areas whose zinc potentialities have not yet been realized, hence it is a minimum that will undoubtedly be augmented to an unknown extent."[13] It seems reasonable to assume that actual additional inferred reserves are still at least 12

[11] See footnote 1, p. 53.
[12] U.S. Bureau of Mines, *Mineral Facts and Problems, 1960 edition* (Washington: U.S. Government Printing Office, 1960), p. 985.
[13] U.S. Bureau of Mines, *Materials Survey: Zinc* (Washington: U.S. Government Printing Office, 1951), p. III-9.

DUP050313980

certainty. (Potential ore is not represented in Figure 12.) Here the situation is similar to that in lead: there is the same unusually small ratio between reserves and identified potential ore in the United States and the same question as to whether this reflects natural circumstances or a lack of attention to potential ore.

THE LEAD-ZINC ANOMALY

The question of resource adequacy in lead and zinc (in the sense of an upward pressure on real costs because of the small magnitude of resources) is academic for the present and short-term future, but it is nevertheless a nagging one.[22] Why is there such a marked absence of information on the potential ores of lead and zinc? There are only two possible explanations: (1) there is relatively little material below present cutoff grades; (2) such material exists, but for some reason there are no data. In either instance the situation with respect to lead and zinc is an anomaly compared to that for the other metals discussed here.

There is evidence in support of both explanations. The lack of data may merely stem from differences between the geology of lead-zinc occurrence and that of the other metals. Since the lead-zinc deposits may be characterized by sharper boundaries, there is little point in pursuing exploration efforts beyond cutoff grade. In many iron and aluminum deposits, on the other hand, similar effort may indicate large tonnages of potential ore because of the lateral continuity of the deposits and the indefiniteness of the deposit boundaries. Moreover, if there is an anomaly in the grade distribution of lead and zinc it would have been noted by the geological and mining professions, yet there is a notable absence of comment on such a circumstance.

Another reason for lack of data could be the prevalence of old districts as the sources of lead and zinc, at least in the United States, in which the continued development of existing mines does not require the delineation of ore and potential ore to the same extent as in new districts. For new districts more information may have to be acquired and made public in order to raise the capital for initial development. The problem of assessing co-products and by-products may also contribute to the lack of data. Finally, it can be argued, again for the

[22] See, for example, C. O. Swanson, "World Reserves of Lead and Zinc," *The Canadian Mining and Metallurgical Bulletin*, May 1960, pp. 346-49.

Lead a
United
explorat
Yet t
relativel
by Lask
others,
centratic
increasi
lead anc
there is
is an im
Perha
World V
United
what wo
The gov
but the r
for curre
duction
tion to t
It cou
grade is
of potent
subsidy p
of potent
that coul
was dire
during V
potential
evitably
potential
ship chan
If this
why has i
tion. The
this adds
course of

in Figure 12.) Here the
the same unusually small
l ore in the United States
ects natural circumstances

)MALY

and zinc (in the sense of
the small magnitude of re-
ıort-term future, but it is
:h a marked absence of in-
c? There are only two pos-
tle material below present
for some reason there are
h respect to lead and zinc
metals discussed here.
ınations. The lack of data
geology of lead-zinc occur-
lead-zinc deposits may be
is little point in pursuing
many iron and aluminum
ıay indicate large tonnages
ıity of the deposits and the
Moreover, if there is an
ıd zinc it would have been
ons, yet there is a notable

be the prevalence of old
:ast in the United States, in
ıg mines does not require
the same extent as in new
ı may have to be acquired
tal for initial development.
by-products may also con-
ı be argued, again for the

serves of Lead and Zinc," *The*
1960, pp. 346-49.

United States, at least, that depressed lead-zinc prices have discouraged exploration for additional reserves of these metals.

Yet there are disturbing arguments and evidence for the existence of relatively little potential ore. The tonnage-grade relationship developed by Lasky for copper has been extended to additional metals by him and others, showing a fairly continuous occurrence across a range of concentration from well above *to well below* cutoff grade, with tonnage increasing as grade declines. There is no *a priori* ground for believing lead and zinc to be exceptions to this relationship; on the other hand, there is nothing in the realm of geology to indicate that such an exception is an impossibility.

Perhaps the strongest evidence is provided by the attempts during World War II and the Korean War to stimulate lead-zinc output in the United States. The government offer to subsidize the exploitation of what would normally be potential ore received a disappointing response. The government approved a high percentage of the proposals it received, but the resulting increase in production was only modest and insufficient for current needs (including stockpiling). The limited increase in production was all the more surprising since the subsidy was large in relation to the current market price.

It could be argued that the distribution of lead-zinc occurrence by grade is such that subsidies must be very high to bring large quantities of potential ore under consideration. But if this were so, the wartime subsidy programs should have yielded knowledge of a very large tonnage of potential ore as a by-product of the industry's efforts to find material that could be worked under the subsidy. Indeed, the exploration effort was directly subsidized and even carried on by the government itself during World War II. The fact that despite this effort the ratio of potential ore to reserves is still low for both lead and zinc leads inevitably to the suspicion that there is, in fact, comparatively little potential ore; or, what is the same thing, that the tonnage-grade relationship changes fairly abruptly not far below current cutoff grades.

If this *is* the anomaly that exists, and not merely a lack of data, then why has it not received attention heretofore? We can offer no explanation. The situation thus remains puzzling, and because of the uncertainty this adds to the long-run outlook for lead and zinc we hope that the course of events will clarify it sooner rather than later.