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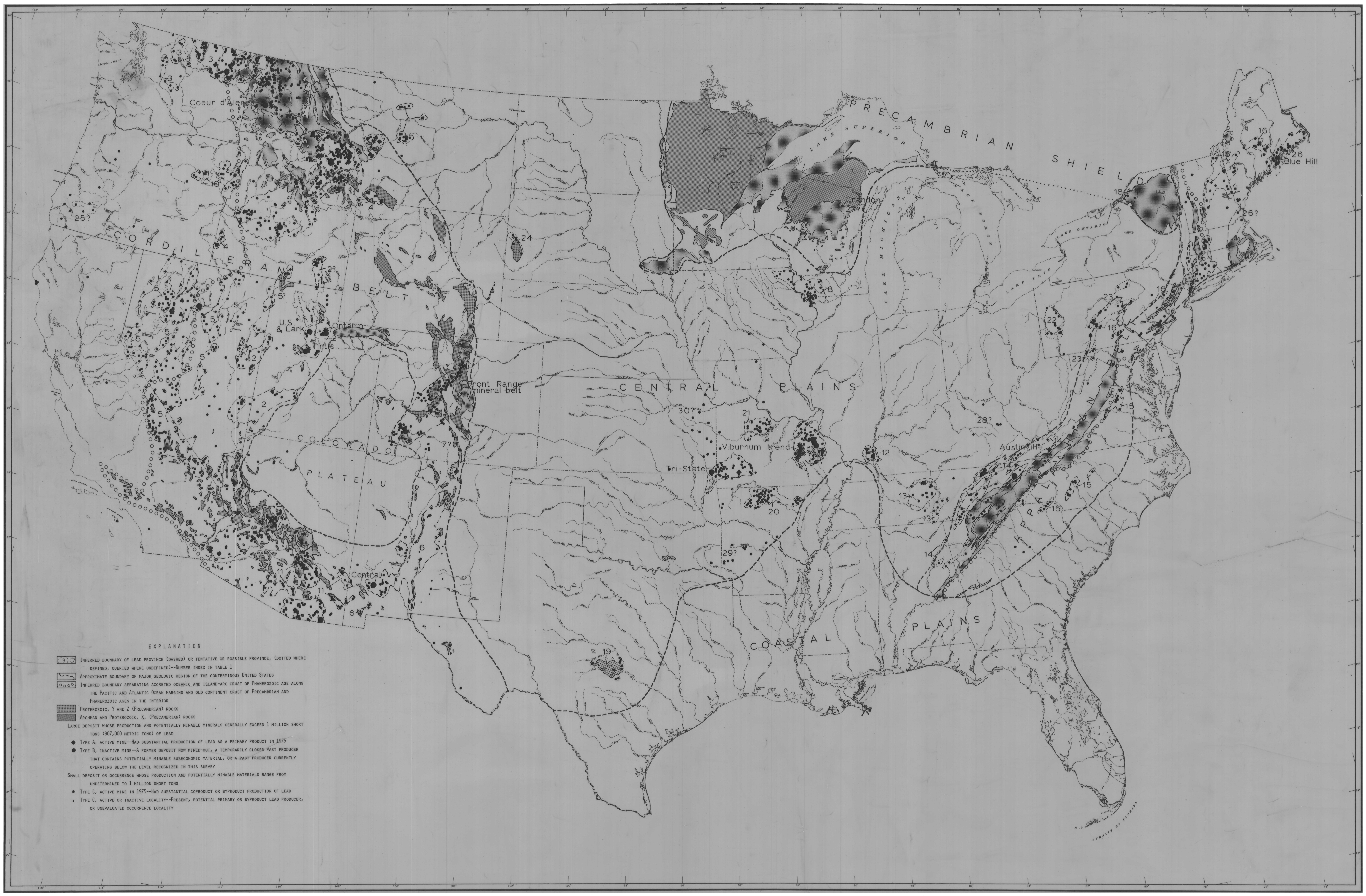

Planimetric Base from National Atlas 1:7 500 000, 1970

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PRELIMINARY MAP OF LEAD PROVINCES IN THE CONTERMINOUS UNITED STATES

By

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INTRODUCTION

The map shows areas, called provinces, that contain deposits of lead, which, because of its high density, malleability, low melting point, and special chemical properties, is an essential and versatile industrial metal. The size and geologic types of lead resource materials, the main geologic environment in which they formed, and preliminary estimates of the magnitude of the resource are indicated for each province.

Apparent consumption of lead in the United States in 1978 was 1,350,000 metric tons (U.S. Bur. of Mines, 1979), of which about 40 percent was produced domestically. Much lead is recycled, and almost [illegible] percent of 1975 (the base year for the atlas survey, Tooker 1979) needs for it were met from scrap, most of the remainder was derived from industrial stocks. A small portion of lead is dissipated in special uses and is nonrecoverable. The nation's net import reliance from Canada, Peru, Australia, and Mexico was 11 percent of the lead apparently consumed in the United States. Substitutes for a number of uses of this metal have been found, but they are currently noncompetitive economically or are scarcer materials themselves. Domestic production of lead eventually may be reduced because of environmental and health considerations attendant to its smelting, a factor that may reduce estimates of future domestic economic availability.

Although most domestic production is from ores mined primarily for lead, more than 13 percent is derived from ores mined mainly for copper, gold, silver, zinc, or fluorspar, in which lead is a coproduct. Significant amounts of other metals, such as antimony, bismuth, gold, silver, tellurium, zinc, indium, and copper are also recovered in processing lead ore concentrates (Ryan and Hague, 1976).

For the next 10-25 years, known domestic lead resources are probably sufficient for most United States' needs. However, Ryan and Hague (1976) estimate that industrial demands for lead will increase. As currently minable minerals are exhausted during the next 20 to 30 years, new deposits of lead, coproduct or byproduct lead produced during the mining of other metals, and recycled lead scrap, as well as imports, will be required to replace the depleted deposits. The map shows province areas where lead exists both in minable deposits and unmeasured occurrences; these provinces are targets for additional geologic study to verify the availability of domestic lead.

The map was compiled chiefly from published reports (McKnight, 1935; Vanderwilt, 1947; Neuschel and McKnight, 1948; McKnight and others, 1962; Barnes, 1956; Heyl and others, 1959; Maine Geol. Survey, 1957, 1958, 1959a, b; Kleinhampl, 1964; Weissenborn, 1966; Stewart, 1966; Wedow and others, 1968; Bowen, 1969, Moore, 1969; Stroud and others, 1969; Cox, 1970; Redden, 1975; Wharton, 1975; West, 1976; Smith, 1977; and McLaughlin and others, 1979) and records of lead resource specialists including those in the computerized resource information bank (CRIB) of the U.S. Geological Survey. We are indebted to Helmuth Wedow, Jr., and J. A. Briskey, Jr., for assistance in identifying less well known occurrences and discussions of recent lead resource information. Geologic information used in defining province boundaries is from the Geologic Map of the United States (King and Beikman, 1974). The rationale of province maps and some of the technical terms and geologic concepts used to highlight resource considerations in the atlas of metal and nonmetal provinces, of which this map is a part, are outlined and discussed in a companion report by Tooker (1979).

DISTINGUISHING MAP FEATURES

The map shows the regional distribution of 31 lead provinces and tentative provinces in the conterminous United States, and provides a summary of current information about the location, size, and areal distribution of known primary or byproduct lead deposits and occurrences, as well as their past or present production status. Table 1, accompanying the map, compares the geologic types of lead concentrations found in provinces and gives a preliminary estimate of the resource possibilities of each province in terms of current geologic knowledge.

A province is an area on the map that contains thinly to densely populated groups and clustered groups of present or former lead-producing deposits and reported occurrences that contain lead in amounts substantially above its average value in the Earth's crust (15 ppm (parts per million), Morris and others, 1973). The metal generally occurs in characteristic geologic settings, although some overlapping or mixed geologic host environments are observed within provinces and may reflect changing geologic conditions with time, or perhaps indicate remobilization and redeposition of lead in that area. A tentative (queried) province represents an indefinite area or one yet to be defined, which on the basis of geologic projection needs to be investigated more thoroughly. No distinction as to economic or subeconomic character is made in this broad definition of a province.

The boundaries of provinces may be based on one or more of several elements. Where possible, province boundaries are drawn on the basis of geologic features, and, as a result, some provinces may consist of a number of detached areas. A boundary may enclose a region that includes favorable rock units, i.e., plutonic or sedimentary, with which lead is known to be concentrated. In some areas, boundaries include adjoining broadly favorable regions in which subeconomic lead occurs but whose distribution is incompletely known. A number of solitary and isolated localities are anomalous in that they do not seem to fall into a regional geologic pattern. When areas containing isolated localities are studied and sampled systematically, the dispersion may correctly indicate little or no resource potential, or provide a new clue to an area that may contain undiscovered lead resources. The purpose of the province map is to identify such possibilities and help narrow the search for domestic lead materials to those areas that contain geologically favorable environments for the deposition of lead minerals.

Lead deposits and occurrences have been classified on the map, for purposes of comparison in the metal and nonmetal province atlas series, into large and small sizes (Tooker, 1979). A large deposit, as defined by McKnight and others (1962), is one whose production and remaining minable or potentially minable lead ores aggregate more than 1 million short tons (907,000 metric tons) of lead. The lead in such a deposit was worth approximately $680 million in 1978 and represented about 80 percent of that year's apparent consumption of lead (based on U.S. Bur. of Mines (1979) data). Small deposits and occurrences are defined as localities containing a known resource of up to 1 million short tons, or containing reported but undetermined amounts of lead.

On most atlas maps the large deposits have been subdivided into those that were active producers in 1975, the base year selected, and those which for a number of reasons were not active, based on U.S. Geological Survey information and in part reported in a world survey of major mines (Mining Mag., 1976). The large producing deposits are designated as type A, shown by a large star symbol, were mined primarily but not exclusively for lead. Type B are former large productive deposits that (1) are mined out, (2) are temporarily closed but may contain an additional subeconomic resource, or (3) are those whose current small production went unnoticed in the survey. The distinction between active and inactive large deposits provides visual evaluation of the relative amount and location of past domestic lead production a compared with current (1975) production localities.

Many small active and inactive deposits and occurrences of lead are shown as type C. Those indicated by a smaller star symbol produced lead as a major coproduct or byproduct of zinc and silver. The deposits or occurrences shown by the small solid dots may or may not have had past primary and byproduct production, and may have possible but limited future capabilities for production, but the resource potential of many of these localities has not been evaluated.

The dominant ore mineral in lead deposits, galena (PbS), occurs in a variety of geologic environments that encompass a broad range of physical and chemical conditions in rocks; some of these characteristic rocks are shown on the map and locally provide a basis for the definition of province boundaries. Based on geologic characteristics, these deposits may be classified into five main groups (Morris and others, 1973): I, fissure veins and replacement bodies (mantos) chiefly in or crosscutting sedimentary rock layers and believed to be associated with adjoining a nearly plutonic intrusives; II, stratabound or stratiform disseminations and cavity fillings (including sedimentary breccias and paleokarsts) mainly in carbonate sedimentary rocks formed following sedimentation, consolidation, and cavity formation; III, stratabound or stratiform deposits, most commonly in carbonaceous shales formed during sedimentation; IV, stratiform volcanogenic massive sulfide layers or lenses in volcanic-derived sedimentary rocks; and V contact metamorphic high-temperature replacement stratiform or irregular skarn deposits closely related to intruding plutonic rocks. Deposits in which galena is a byproduct are formed in geologic environments that are, for the most part, similar to the same types.

In addition, there seems to be broadly defined continent-wide control on the concentration of lead in crustal rocks, which undoubtedly was constrained by as yet poorly understood plate tectonic processes. Lead provinces for the most part seem to be closely identified with characteristic geologic environments and host rocks in the two main crust plates--accreted oceanic and island-arc, and old continent--as defined by Tooker (1979). The most prominent concentrations of the metal seem to have been in old continent crust, which contains Archean and(or) Proterozoic (Precambrian) basement and Phanerozoic cover rocks (Tooker, 1979). Provinces appear to be localized in a broad zone along the edges of the old continent plate and along several prominent, broad, somewhat discontinuous, northeast-trending zones. Another general but repeated correlation is with northeasttrending uplifted belts of Precambrian rocks and conterminous Cenozoic intrusives. The deposits, however, are most often located in the Phanerozoic cover rocks, which provided hospitable concentration sites. There are virtually no significant concentrations of deposits, and only a few occurrences reported currently in the accreted oceanic and island-arc derived terranes.

LEAD PROVINCES

Thirty-one provinces and tentative provinces (where queried, boundaries as yet undefined) that contain known as well as untested lead resource possibilities are located on the map and compared in table 1. The first eight provinces are listed in order of their recent production importance, the remaining areas are listed randomly. Table 1 also contains our preliminary evaluation of the potential for discovery of additional lead resources, and of the adequacy of geologic information available to us for making such estimates.

The United States was a substantial producer of lead as demonstrated by the fact that there were a number of substantial producers in 1975 and that net-import reliance as a percent of apparent consumption was only slightly more than 10 percent. There were 12 type A mines producing lead as the primary product, and 9 type C deposits in which lead was an important coproduct or byproduct of zinc or silver production. Geographically these major producing deposits in the conterminous United States (table 2) lie in four broadly defined geologic and structural environments, according to McKnight and others (1962): (a) the Great Basin region of Nevada, western Utah, southeastern California, southern Arizona, and New Mexico; (b) the Rocky Mountains in the Cordilleran belt from Canada to Mexico; (c) broad uplifts within the central part of the Mississippi Valley region of the Central Plains; and (d) the folded Appalachian (mountain) belt from Maine to Alabama.

Major United States production in recent years has been from deposits in province 1 in Missouri (Ryan, 1975). Here (and also in provinces 8, 9, 12, 13, 18, 20, 21, 22, and 28?) lead was concentrated mainly in deposits and occurrences of the Mississippi Valley type. In these provinces stratiform lead deposits occur locally as open-space breccia and vein fillings, and as bedded replacements in early Paleozoic carbonate (platform) rocks that lie along the margins of uplifted regions. These concentrations of lead seem to have no close association with igneous rocks.

The other significant domestic producing provinces are in the Cordilleran belt in Idaho and Washington (provinces 3 and 4), Colorado (province 7), and Utah (province 2). In contrast to province 1, lead was concentrated here in a variety of geologic deposit types (table 1) from hydrothermal solutions presumably derived from adjacent igneous rock sources; oxidation during weathering has altered lead in the upper parts of many deposits and occurrences. Provinces 3, 4, 5, 10, and 11 are located along the margins of old continent crust and provinces 2, 3, 4, 5, 6, and 7 extend northeastward in discrete zones. The Colorado Plateau seems to contain virtually no lead occurrences even though intersected by projections of the northeast-trending mineral zones.

The Appalachian belt contains two main types of deposits. Those along the west side in provinces 14 and 23 are similar to Mississippi Valley types that occur in early Paleozoic (platform) carbonate rocks. Those along the east side (provinces 15 and 16) are located mainly in Piedmont crystalline rock terranes and are composed largely of disseminated or massive sulfide and replacement deposits that contain other base metals as well.

While most provinces, and particularly those containing large deposits, are found on the old continent crust plate, provinces 10, 25(?), and 26 are mainly massive sulfide concentrations associated with oceanic crust. Byproduct lead eventually may be developed from such localities. The coastal Maine deposits seem to be a volcanogenic-type massive sulfide, possibly formed in an oceanic-type environment.

As previously noted, all major lead deposits are closely associated with belts of Archean and Proterozoic (Precambrian) and Phanerozoic rocks on the old continent crust plate. Except in the Adirondack Mountains, in province 18, lead was not known to occur in abundance in Precambrian shield areas of the midcontinent. Discoveries of base metals at Crandon, Wis. (province 27?), in a Precambrian volcanogenic massive sulfide deposit, may indicate future discovery of additional similar buried shield occurrences, which are extensions southward of a well-known Canadian deposit environment.

The occurrence of lead in a variety of geologic types of deposits of wide-ranging ages, some of which are associated with intrusives, seems to suggest that, at least locally, lead may have been remobilized and redeposited during geologic time and that its metallogenesis is complex. Possibilities for concentrations of disseminated lead in the sedimentary stratabound environment have not been fully examined in the conterminous United States, although elsewhere in the world this type of deposit has been a source of important production.

Background information relating to this map and others in the Atlas of Metal and Nonmetal Provinces in the Conterminous United States is published as U.S. Geological Survey Circular 792 (Tooker, 1979), available free of charge from the U.S. Geological Survey, Branch of Distribution, 1200 South Eads St., Arlington, VA 22202.

Table 1.--*Location, types of deposits, estimates of resource potential, and status of geologic resource knowledge of lead provinces in the conterminous United States*

Province			Geologic types of deposits[1]	Preliminary estimates of resource potential[2]			Status of geologic resource information	
No.	State	Area		High	Medium	Low	Adequate	Insufficient
1	SE Missouri	Viburnum trend district	II	X	--	--	--	X
2	SE Idaho, western Utah and SW Nevada	Eastern Great Basin	I	X	--	--	--	X
3	NE Washington, northern Idaho, and NW Montana	Northern borderland (Coeur d'Alene)	I and II	X	--	--	--	X
4	Central Idaho and western Montana	Butte vicinity	I, II, and VI	--	X?	--	--	X
5	Nevada, eastern California, and southern Idaho	Western Great Basin	I	--	X	--	X	--
6	New Mexico	Rio Grande rift	I and V	--	X	--	--	X
7	Colorado	Front Range Mineral belt	I and II	--	X	--	X	--
8	Wisconsin, Iowa, Illinois	Upper Mississippi Valley district	I and II	--	X	--	X	--
9	SE Kansas, SW Missouri, and NE Oklahoma	Tri-State district	I and II	--	X?	--	X	--
10	NE Oregon	Powder River	I and II	--	--	X	--	X
11	SE California, and southern Arizona	Southern border	I, II, and IV	--	--	X	--	X
12	Illinois-Kentucky	Hicks Dome	I	--	--	X?	--	X
13	Central Tennessee	Nashville Dome	I and II	--	--	X	--	X
14	E. Tennessee, W. North Carolina, Alabama, Georgia, South Carolina	Southern Appalachian Mountains, western belt	I and IV	--	--	X	--	X
15	Virginia, North Carolina, and South Carolina	Piedmont, Appalachian Mountains, east belt	I and IV	--	--	X	--	X
16	New England States, New York, Pennsylvania	Northern Appalachian Mountains	I	--	--	X	--	X
17	Virginia, North Carolina, South Carolina, Tennessee, Georgia, and Alabama	Southern Appalachian Mountains, central belt	I, IV, and V	--	--	X	--	X
18	New York	Adirondack Mountains	I	--	--	X	--	X
19	Southwest Texas	Llano uplift	I	--	--	X	--	X
20	Arkansas	Northern district	I	--	--	X	X	--
21	Missouri	Central district	I	--	--	X	X	--
22	Pennsylvania	Western basin	II	--	--	X	--	X
23	Pennsylvania and Maryland	Central Appalachian Mountains	II	--	--	X	--	X
24	South Dakota	Black Hills	I	--	--	X	X	--
25?	Southwest Oregon	Klamath Mountain	IV	--	--	X?	--	X
26	Maine and Massachusetts(?)	Coastal area	I and IV	--	X	--	--	X
27?	Wisconsin	Crandon area	IV	--	X?	--	--	X
28?	Indiana, Ohio and Kentucky	Cincinnati arch	II and IV		Unknown		--	X
29?	Arkansas	West-central	I, II	--	--	X	--	X
30?	Kansas, Missouri, and Iowa	Coal basin	I, II		unknown		--	X

[1]Index to types of deposits; source, Morris and others (1973).
- I. Fissure veins, breccias, and replacement bodies (mantos) in sedimentary rocks, generally related to intrusive bodies.
- II. Stratiform or stratabound disseminations and cavity fillings (including paleokarsts) in carbonate sediments, formed after sedimentation.
- III. Stratiform and stratabound deposits in shale, formal during sedimentation.
- IV. Stratiform volcanogenic massive sulfide deposits.
- V. Skarn deposits.

[2]A high estimate indicates the presence or expectation of more than one large (type A or B) deposits; a low estimate is based on the presence of type C deposits and (or) occurrences alone.

Table 2.--*Geographic distribution of major productive lead deposits*

	Type A (active)	Type B (inactive)	Type C (active)	Total, all lead deposits	Percent of 1973 production (approximate)
	Primary lead	Primary lead	Coproduct or byproduct lead		
Great Basin part of Cordilleran belt	2	5	---	7	>2
Rocky Mountains part of the Cordilleran belt	2	4	7	13	16
Mississippi Valley (Ozark, uplift), Central Plains[1]	6	4	2	12	81
Folded Appalachian belt	2	1	---	3	<2
Total	12	14	9	35	100

[1]Includes more than 80 percent of all domestic production in 1973 (Ryan, 1975).

REFERENCES CITED

Barnes, V. E., 1956, Lead deposits in the Upper Cambrian of central Texas: Texas University, Bureau of Economic Geology Report Investigation, no. 26, 68 p.
Bowen, R. G., 1969, Copper, lead, and zinc, in Mineral and water resources of Oregon: U.S. Congress, 90th, 2d Session, Senate Committee Interior and Insular Affairs, Committee Print, p. 120-125.
Cox, D. P., 1970, Lead-zinc-silver deposits related to the White Mountain Plutonic Series in New Hampshire and Maine: U.S. Geological Survey Bulletin 1312-D, p. D1-D18.
Heyl, A. V., Jr., Agnew, A. F., Lyons, E. J., and Behre, C. H., Jr., 1959, The geology of the upper Mississippi Valley zinc- lead district: U.S. Geological Survey Professional Paper 309, 310 p.
King, P. B., and Beikman, H. L., 1974, Geologic map of the United States: U.S. Geological Survey Map, scale 1:250,000.
Kleinhampl, F. J., 1964, Metallic mineral resources--Silver, lead, and zinc, in Mineral and water resources of Nevada: U.S. Congress, 88th, 2d Session, Senate Document 87, p. 138-150.
Maine Geological Survey, 1957, Bangor sheet: Maine Geological Survey Mineral Resource Reference Map Series, M.R.R.M. 1, scale 1:250,000.
______1958, Maine metal mines and prospects: Maine Geological Survey Mineral Resources Index no. 3, 53 p.
______1959a, Lewiston sheet: Maine Geological Survey Mineral Resource Reference Map Series, M.R.R.M. 2, scale 1:250,000.
______1959b, Portland-Bath sheet: Maine Geological Survey Mineral Resource Reference Map Series, M.R.R.M. 3, scale 1:250,000.
McKnight E. T., 1935, Zinc and lead deposits of northern Arkansas: U.S. Geological Survey Bulletin 853, 311 p.
McKnight, E. T., Newman, W. L., Heyl, A. V., Jr., 1962, Lead in the United States, exclusive of Alaska and Hawaii: U.S. Geological Survey Mineral Investigation Resource Map MR-15, scale 1:3,168,000.
McLaughlin, R. J., Sorg, D. H., Olin, H. N., and Heropoulos, Chris, 1979, Base- and precious-metal occurrences along the San Andreas fault, Point Delgada, California: U.S. Geological Survey Open-File Report 79-584, 11 p.
Mining Magazine, 1976, International Mining Survey, Table B-- 1,126 mines accounting for 90 percent of all output other than coal: v. 135, no. 3, p. 237.
Moore, R. T., 1969, Lead and zinc, in Mineral and water resources of Arizona: U.S. Congress, 90th, 2d Session, Senate Committee Interior and Insular Affairs Committee Print, p. 182-205.
Morris, H. T., Heyl, A. V., Jr., and Hall, R. B., 1973, Lead, in United States mineral resources: U.S. Geological Survey Professional Paper 820, p. 313-332.
Neuschel, V. S., and McKnight, E. T., 1948, Map showing metallic mineral deposits of Missouri: U.S. Geological Survey Missouri Basin Studies no. 18, scale 1:1,000,000.
Redden, J. A., 1975, Lead-silver and lead-zinc deposits, in Mineral and water resources of South Dakota: U.S. Congress, 94th, 1st Session, Senate Committee Interior and Insular Affairs Committee Print, p. 90-95.
Ryan, J. P., 1975, Lead, in Minerals yearbook 1973: U.S. Bureau of Mines, v. 1, p. 688.
Ryan, J. P., and Hague, J. M., 1976, Lead, in Mineral facts and problems, 1975 edition: U.S. Bureau of Mines, p. 591-610.
Smith, R. C., 1977, Zinc and lead occurrences in Pennsylvania: Pennsylvania Geological Survey, 4th Series, Mineral Resource Report 72, 317 p.
Stewart, R. M., 1966, Lead, in Mineral resources of California: U.S. Congress, 89th, 2d Session, Committee Interior and Insular Affairs, Committee Print, p. 216-221.
Stroud, R. B., Arndt, R. H., Fulkerson, F. B., and Diamond, W. G., 1969, Mineral resources and industries of Arkansas: U.S. Bureau of Mines Bulletin 645, 418 p.
Tooker, E. W., 1979, Background information to accompany the atlas of metal and nonmetal mineral provinces in the conterminous United States: U.S. Geological Survey Circular 792 (in press).
U.S. Bureau of Mines, 1979, Mineral commodity data summary 1979: U.S. Bureau of Mines, p. 86-87.
Vanderwilt, J. W., 1947, Mineral resources of Colorado: Colorado Mineral Resources Board, Denver, Colo., pl. 4.
Wedow, Helmuth, Jr., Heyl, A. V., Jr., and Sweeney, J. W., 1968, Zinc and lead, in Mineral resources of the Appalachian region: U.S. Geological Survey Professional Paper 580, p. 450- 466.
Weissenborn, A. E., 1966, Silver, lead, and zinc, in Mineral and water resources of Washington: U.S. Congress, 89th, 2d Session, Committee Interior and Insular Affairs, Committee Print, p. 125-141.
West, W. S., 1976, Lead and zinc, in Mineral and water resources of Wisconsin: U.S. Congress, 94th, 2d Session, Committee Interior and Insular Affairs, Committee Print, p. 132-145.
Wharton, H. M., 1975, Introduction to the southeast Missouri lead district, in Guidebook to the geology and ore deposits of selected mines in the Viburnum Trend, Missouri: Missouri Survey Report Investigation 58, 60 p.