OPEN-FILE REPORT
79-576Q

PRELIMINARY MAP OF ZINC PROVINCES IN THE CONTERMINOUS UNITED STATES

By

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1980

Scale 1:5,000,000

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

INTRODUCTION

The map shows the distribution in the conterminous United States of anomalous concentrations of zinc, which is an essential commodity used in metal alloys, chemicals, additives, and pigments. The United States has ample supplies of unmined zinc minerals, and excellent possibilities to discover additional potentially minable materials. Nonetheless, domestic zinc production was about one-third of apparent consumption in 1973, and net import reliance was about 40 percent. There is some recycling of zinc from scrap (data from U.S. Bur. Mines, 1978), but much is dissipated in use and is not recoverable. Commarota and others (1976) have projected an increased demand of at least 2.5 percent annually through year 2,000 for the metal. The purpose of the zinc province map is to show the location and magnitude of current production as well as the location of areas of undeveloped potential domestic sources that should be investigated to determine the geologic availability of zinc for meeting anticipated future needs.

The geologic characteristics favorable for concentrating zinc appreciably above its average amount in crustal rocks (0.04 percent by millionth) are numerous (Wedow and others, 1973). Most economic concentrations are as zinc sulfide or oxide minerals. Fifty-seven percent of domestic production in 1973 was from ores mined primarily for zinc, 19 percent was obtained as a coproduct of zinc-lead ores, and 23 percent as a byproduct of lead, copper-zinc, copper-lead, or copper-lead-zinc ores (McMahon and others, 1975).

The map, part of an atlas of metal and nonmetal provinces (Tooker, 1979), was compiled from a number of published reports (McKnight, 1935; Vanderwilt, 1947; Herbert and Young, 1956; McKnight and others, 1962; Beyl, 1963, 1964; Beyl and Boxins, 1962, 1964; Kleinhampl, 1964; Norton, 1966; Wedow and others, 1968; Norton, 1969; and Beyl, 1978), and records of zinc resource specialists in the U.S. Geological Survey. We owe special thanks to H. T. Morris and J. A. Briskey, U.S. Geological Survey, for compiling information on the Precambrian Shield. Geologic and geographic information used for 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 discussions are defined and discussed in a companion background report by Tooker (1979).

DISTINGUISHING MAP FEATURES

The map shows the regional distribution of 32 zinc province or tentative province areas in the conterminous United States and provides a summary of current information about the location, size, and areal distribution of known primary, coproduct, or byproduct zinc deposits or occurrences, as well as the past and future resource status. Table 1, which accompanies the map, identifies the host geologic terranes in which zinc concentrations are found in provinces, and gives our preliminary estimates of their resource possibilities.

A province on this map is a region that contains thinly or clustered groups of zinc deposits or occurrences that were found generally in comparable geologic settings. In some provinces overlapping or mixed geologic environments may indicate changed geologic conditions with time, and perhaps suggest that zinc was remobilized and redeposited by postdepositional structural and thermal events. No distinction as to economic or subeconomic character of a province is made in the definition of provinces. Where possible, boundaries are drawn on the basis of geologic criteria and, as a result, some provinces may consist of a number of detached but regionally grouped areas. A boundary, however, also may enclose a number of closely spaced deposits in a region that is not known well enough or, in most cases, boundaries may include adjoining favorable regions in which subeconomic zinc occurs but which have not been explored adequately. In the absence of a prominent mappable feature, province boundaries enclose groups of localities that share geologic characteristics. A number of solitary localities are also present that do not seem to fall into a regional geologic framework and may represent anomalous or incompletely investigated occurrences. When these areas are systematically studied and geologically sampled, the individual occurrences may indeed turn out to have little resource potential. Such localities, nevertheless, also may be recognized finally as a part of long enclosed areas that in reality have extensive undiscovered zinc-resource potential.

Zinc deposits and occurrences on the map are separated into large and small sizes for purposes of comparison in the atlas series (Tooker, 1979). A large deposit, as defined by McKnight and others (1962), contains more than 1 million short tons (907,000 metric tons) of zinc metal, which would be worth a minimum of about $620 million, on the basis of U.S. Bureau of Mines (1979) information. For ease of comparison, a large deposit would contain about 70 percent of the apparent United States' consumption in 1973, the base year used in the atlas. Small deposits or occurrences of zinc are defined as those containing less than 1 million short tons, or as yet undetermined amounts, and chin includes both the small- and medium-sized districts of McKnight and others (1962).

The large deposits have been subdivided in the atlas into those which were active producers in 1975 and those which for a number of reasons were not active, based on U.S. Geological Survey information and also reported in a world survey of mining (Mining Mag., 1976). The large producing deposits that were mined primarily, but not exclusively, for zinc (large solid spot) are distinguished on the map as type A. Type B (large solid spot) are from large formerly productive deposits that are mined out, or are temporarily closed, or are producing coproduct or byproduct zinc, or currently small producers that seem restricted in the survey. Those large economic deposits about to become producers are shown as a large open spot. The distinction between active and inactive large deposits provides a visual evaluation of the relative amount and location of past domestic zinc production as compared with current (1975) production sites.

Many small active and inactive deposits or occurrences of zinc are shown as type C. Those indicated by a small star symbol were mined as a coproduct or byproduct of other base metals (McMahon and others, 1975, table 6). The deposits or occurrences shown by the small solid dots may have had modest past production and may have only fair future resource capability as primary or byproduct sources of zinc, but many type C localities have unknown resource potential.

In terms of broad regional distribution, zinc provinces seem to be most closely identified with the Precambrian basement rocks of the stable continent crustal plate cocks, as defined by Tooker (1978, 1979). Only a few occurrences are reported in oceanic and island-arc derived crust rocks, which were accreted to the old continent. Further, there is a persistent correlation of zinc localities with the uplifted regions of old continent crust where Precambrian rocks are exposed; however, the deposits most often are localized, in sedimentary or intrusive Phanerozoic cover rocks.

Because zinc is concentrated in the crust under widely-ranging physical and chemical conditions, its occurrence in a variety of geologic units is not surprising; the area dimensions of some of these units are shown on the map. The following discussion about types of deposits is based on the results of the discussions of Wedow and others (1973). The metal occurs in rock-forming (silicate) minerals only in trace amounts, but it is a major constituent of a few silicate minerals from magmatic processes, and by fossil water brines trapped in rocks at the time of deposition of sedimentary basins. Most primary ore fluids precipitate zinc chiefly as the zinc sulfide sphalerite. Zinc occurs as the major constituent of many ore bodies, or as a coproduct or byproduct material in iron, lead, copper, silver, and gold deposits. Sphalerite can be redistributed by acid waters during weathering at the Earth's surface, the zinc leached and reprecipitated elsewhere as carbonate or silicate minerals in the near-surface zone of oxidation. Thus, zinc deposits are closely associated with igneous rocks, and with sedimentary rocks and their metamorphosed counterparts, as well as occurring in sufficial deposits; there may be gradations from one type of occurrence to another. The metamorphosed border zones of intrusive igneous rock may be the site of contact skarn zinc deposits, or the intrusive igneous rock may be the site of contact silicification of existing rock) stratabound replacement metamorphic halo irregular, epigenetic (concentration existing rock) stratabound replacement deposits, and veins in the intrusive and surrounding host rocks. Veins (open-space), fillings occur both in the plutons, near its outer contact, and in the enclosing sedimentary rocks. In metamorphosed volcanic and sedimentary rock terranes, layered strata are hosts for lenticular massive sulfide deposits. Another important group of stratabound deposits--the Mississippi Valley type--occur in carbonate rocks along the basin platform margins adjoining areas of uplift; the zinc deposits do not seem to be associated with igneous activity. Locally brecciated zones provide sites for irregular, relatively local epigenetic open-space filling and replacement deposits. Stratiform zinc deposits of the Superschister type occur in relatively thin strata such as oil shales and evaporite beds and may occur over large regions. Laterites formed by weathering in more humid climatic conditions may also concentrate zinc.

ZINC PROVINCES

Relatively abundant zinc resources, widely distributed in most parts of the conterminous United States, are localized in 36 provinces, subprovinces, and tentative (or queried) provinces on the map and in table 1. The first 10 provinces are listed in approximate order of decreasing production (McMahon and others, 1975, table 5); the remaining areas are listed randomly. Zinc occurs in a variety of geologic settings within many provinces, but large economic deposits occur in only 12 widely dispersed provinces. Table 1 also contains our preliminary evaluation of the potential for discovery of new zinc deposits or extensions of known ore bodies, and assesses the adequacy of geologic resource information available for making such estimates. The United States was a substantial producer of zinc in 1975: there were three large type A mines extracting zinc as the primary metal, 11 type A mines that produced zinc as a coproduct or byproduct, and 4 type B mines. In addition, 13 of the small type C deposits produced substantial amounts of coproduct or byproduct zinc during mining for other metals. Geographically, large zinc production in the conterminous United States has come from deposits in or peripheral to the Central Plains, as well as from the Cordilleran and Appalachian belts. The Precambrian Shield promises to become a more important source area. The 15 provinces and tentative province in the Central Plains already have provided large zinc production and retain a high potential for extensive future primary or byproduct production. Deposits in provinces 2, 8, 12, 14, 18, 23, 24, 27, and 28 are mainly stratabound replacement and open-space fillings in carbonate sediments, which generally border uplifted regions but are not obviously related to known igneous activity. Less well known are stratiform zinc concentrations found disseminated in thin shale, oil shale, or evaporited beds in sedimentary basinal rocks, as shown by the (?) symbol, in provinces 1, 4, 5, 7, 10, and tentative province 32. Deposits in provinces 15, 16, 17, 19, 20, 21, 22, and 26a. Zinc commonly is concentrated in the Cordilleran belt by hydrothermal solutions derived from adjacent igneous sources. Similar concentrations at Hicks Dome, province 19, seems to be a rare example of hydrothermal zinc related to igneous activity in the Central Plains.

Stratabound zinc provinces, mostly of the Mississippi Valley type, are spaced at intervals along two broad northeast-trending zones that seem to parallel axes of uplifted and locally exposed basement rocks. The most prominent zone lies in a band from Oklahoma and Arkansas to northern Illinois and Indiana; it lies roughly between the coal basins (shown as provinces 23 and 24) and is closely associated with faulted uplifted basement rocks. The narrower zone, from Alabama to western Pennsylvania, is along a series of down-dip segments of the eastern edge of the Appalachian basin (immediately west of the Appalachian belt), and east of the Mississippi embayment--New Madrid fault system. Most of the stratabound deposits and occurrences are in the subsurface. Province 8, which is associated with the Nashville dome, is already productive.

A potentially large but as yet unevaluated future resource in the Central Plains may be the zinc sulfides that fill fractures in coal beds in the Illinois and Lower-Kansas-Missouri coal basins. Preliminary studies by Hatch and others (1976a, b) indicate that if recovered from present coal waste, the nation's production of zinc could be increased substantially. The occurrence of significant zinc in other eastern coal basins, which, by and large, also contain high-sulfur coal, has not yet been evaluated. No comparable occurrences have been reported in the low-sulfur coal basins in the western United States. One suggestion of a probable source of zinc is that the host sphalerite in coal cleats is from zinc leached from the thick, zinc-rich volcanic ash beds in the Rocky Mountain coal basins.

The Hicks Dome, a local uplifted coal structure lying along the northern course of the New Madrid-Mississippi embayment fault zone, which borders the east side of the Ozark uplift, is the site of a group of fluorite-barite-lead deposits and occurrences, province 19. Mafic rocks, intrusive volcanic breccia plugs and dikes, and an alkalic pluton at depth are possible sources of solutions that produced hydrothermal alteration of wallrocks and the vein and bedding replacement deposits.

A paucity of zinc as well as deposits and occurrences of other metals along the western Central Plains may represent deep burial of source rocks, structures, and depositional sites. Except for the Black Hills (province 307 where Precambrian basement rocks crop out) and in an uplifted outlying part of province 15 in Montana, there are virtually no occurrence of zinc in the western part of the Central Plains.

The Precambrian Shield provinces (1 and 13) contain a current major producer and at least one large potential deposit. Those at Balmat, N. Y., were probably concentrated by high-temperature metamorphism of Precambrian sediments that originally contained disseminated sulfides. Localities in northern Wisconsin, especially at Crandon, on the other hand, contain zinc in volcanogenic massive sulfides.

Major deposits in the western part of the Appalachian belt, in provinces 3, 3a, 6, 11, and 21, contain zinc sulfide mainly in open-space breccia and vein fillings and bedded stratabound replacements in early Paleozoic carbonate sedimentary rocks. Weathering has oxidized the upper parts of many of these deposits, producing peripheral secondary concentrations of zinc. East of these provinces, in the Piedmont crystalline rocks, are a few deposits and occurrences (province 22) of continental plates, in a different type of zinc concentration comprising veins, disseminated, or massive sulfide deposits in which sphalerite is their base metals. Provinces 20, 22, and 39 are included in this group of deposits in which zinc is most often a byproduct material; there are few large deposits found therein. The size of the newly discovered Bald Mountain deposit (province 29) is incompletely known, but its discovery opens a new terrane for exploration. Volcanogenic massive sulfide type deposits in province 7, in probable oceanic crust, also have provided some byproduct zinc.

The Cordilleran belt is composed of three parts--old continent, accreted oceanic crustal assemblages, and the Colorado Plateau. In the eastern part of the Cordilleran belt old continent crust is composed of Archean and Proterozoic (Precambrian) basement and Phanerozoic cover rocks. Cordilleran belt zinc deposits and occurrences are concentrated in the eastern part of the belt in areas of old crust. Zinc deposits and occurrences comprise 10 provinces discussed in regular patterns. Provinces 9, 10, 14, 16, 17, and 18 line along the diffuse western margin of the old continent crust plate, east of the oceanic crust additions which seem to contain relatively little zinc. Five northeast-trending zones, more or less evenly spaced (about 200 miles (300 km) apart) project into the old continent crust from this margin zone. The zones include: crystalline rock terrane in the northwest (province 9) that apparently extends northward into Canada, the central Idaho-Butte zone (province 15, and possibly 16); the eastern Great Basin (province 9); the Arizona Great Basin (province 17, which may possibly connect to the northeast with provinces 97, 307, and 317); the Rio Grande rift zone (province 10); and the Colorado Front Range mineral belt (province 9, and possibly a southwestern extension into part of 17). Recent reports of discovery of replacement zinc and copper at Pinon Alton, N. Mex. (province 10), and at Jerome, Ariz. (province 17), in addition to the Butte, Mont. (province 15) deposits, demonstrate that this province still has real resource potential. Large deposits or dense clusters of smaller deposits and occurrences are spaced somewhat regularly and lie near the intersection of these broad northeast zones and some of the major continental northwest-trending basement flaw or lineament zones (Tooker, 1978). Small occurrences, however, are generally distributed more or less evenly along the northeast belts, which coincide with uplifted Precambrian basement rocks as well as with numerous small Tertiary intrusive bodies. Zinc is concentrated mainly in covering Phanerozoic host rocks. Province 14, in the western Great Basin, seems particularly broad and diffuse and contains no large deposits. Borders of individual parts of this province are defined by Phanerozoic cover rock fault and outcrop map patterns of that area, which are complicated by extensive Tertiary lava flows. Deposits and outcrop map patterns of that area, along broad northeast-trending basement structures, which seem from more deeply buried concentrations, along broad northeast-trending basement structures, which seem to be the controlling factor in zinc (Tooker, 1978). An exception to the province distribution pattern is the Colorado Plateau, which is part of the old continent crust plate that is virtually devoid of zinc occurrences. The plateau is surrounded by a large number of important deposits, as well as numerous occurrences. The basement rocks are thickly covered here, and rock lithology and structure apparently were unfavorable for the concentration of zinc. The westernmost coastal part of the Cordilleran belt is considered to represent oceanic and island-arc terranes successively accreted (added) to the craton (old continent) during Phanerozoic time. Very few, and generally only small byproduct occurrences of zinc were concentrated in tentative provinces, 307 and 327, which contain the metal mostly in volcanogenic massive-sulfide type deposits.

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

No.	Province: State	Province: Area	Geologic types of deposits./	Preliminary estimates of resource potential: High	Medium	Low	Status of geologic resource information: Adequate	Insufficient
1	New York	Balmat district	V	X	--	--	--	X
2	Missouri	Southeast lead district	V	X	--	--	--	X
3	Virginia, Tennessee, North Carolina, and Georgia	Western part of Southern Appalachian Mountains	II, III, V	X	--	--	--	X
3a	Virginia	Shenandoah Valley	III, V	--	--	X	X	--
4	Colorado	Front Range mineral belt	II, III, WII	--	X	--	--	X
5	Washington, Idaho, and Montana	Northern border (Coeur d'Alene-Metaline districts)	I, II, III	--	X	--	--	X
6	New Jersey	Sterling district	II	--	X	--	X	--
7	Maine	Blue Hill district	II	--	X	--	X	--
8	Tennessee and Kentucky	Central	V	X	--	--	--	X
9	Western Utah and eastern Nevada	Eastern Great Basin	II, III, WII	--	X	--	--	X
10	New Mexico	Rio Grande rift zone	I, II, III, WII	--	X	--	--	X
11	Pennsylvania	Friedensville district	II, III	--	X	--	--	X
12	Wisconsin, Illinois, and Iowa	Upper Mississippi Valley district	V	X	--	--	--	X
13	Wisconsin	Northern	II	X?	--	--	--	X
14	Kansas, Oklahoma, and Missouri	Tri-State district	V, WII, IX	--	X	--	X	--
15	South-central Idaho and SW Montana	Hailey-Butte trend	I, II, III	--	--	X	--	X
16	Western Nevada and eastern California	Southwestern border (Basin and Range)	I, II, III, IV	--	--	X	--	X
17	Arizona	Southwestern border (Basin and Range) IV, WII	I, II, III, IV	--	--	X	--	X
18	Arkansas	Northern	V	--	--	X	X	--
19	Illinois and Kentucky	Hicks Dome district	III	--	--	X	--	X
20	New Hampshire, Vermont, Massachusetts, Connecticut, and New York	Northern Appalachian Mountains	III, VI	--	--	X	--	X
21	Pennsylvania, Maryland, and Virginia	Central Appalachian Mountains	III	--	--	X	--	X
22	Virginia, North Carolina, Georgia, and Alabama	Piedmont and eastern part of Southern Appalachian Mountains	III, VI	--	--	X	--	X
23	Iowa, Missouri, Kansas, and Oklahoma	Coal basin	V	unknown			--	X
23a		do	VI	unknown			--	X
24	Illinois	Coal basin	V, VI(?)	X	--	--	--	X
25	Western Pennsylvania	Pittsburgh region	V	unknown		--	--	X
26	Southern Ohio	Columbia region	V	unknown		--	--	X
27	Central Kentucky	Cincinnati arch	V	unknown (buried)			--	X
28	Missouri	Central lead district	V	--	--	X	--	X
29	Maine	Bald Mountain	IV	X	--	--	--	X
30?	South Dakota	Black Hills	VI	--	--	X	--	X
31?	Oregon and Idaho	Hells Canyon region	?	--	--	X	--	X
32?	California	Sierra foothills fault zones		--	--	X	--	X
33?	Wyoming and Colorado	Continental divide		--	--	X	--	X
34?	Arkansas and Oklahoma	West Central	VI	unknown		--	--	X

./ Index to geologic type of deposits and occurrences:

Associated with igneous rocks
- I Contact metamorphic skarn zone bordering intrusive
- II Stratabound, irregular replacement (manto) in carbonate rocks bordering or away from intrusive or extrusive rock or dissemination in sedimentary rocks
- III Vein or open space filling in intrusive and (or) intruded host rock near contact, shear zone, and breccia pipes

Associated with sedimentary and metasedimentary rocks
- IV Stratabound, massive sulfide, often a volcanogenic sediment
- V Stratabound replacement and open space filling in platform carbonate rocks and breccia (local area, irregular shape) or cleats in coal basin deposits
- VI Stratiform, disseminated in thin shale, oil shale, or evaporate layers schist (broad area, regular shape)

Weathering products of older rocks
- VII Supergene (oxidized) enrichment
- VIII Laterite
- IX Residual deposits, sinkhole filling

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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 Eads St., Arlington, VA 22202.

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature.