DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

ATLAS OF METAL AND NONMENTAL MINERAL PROVINCES CONTERMINOUS U. S.

OPEN-FILE REPORT

79-576D

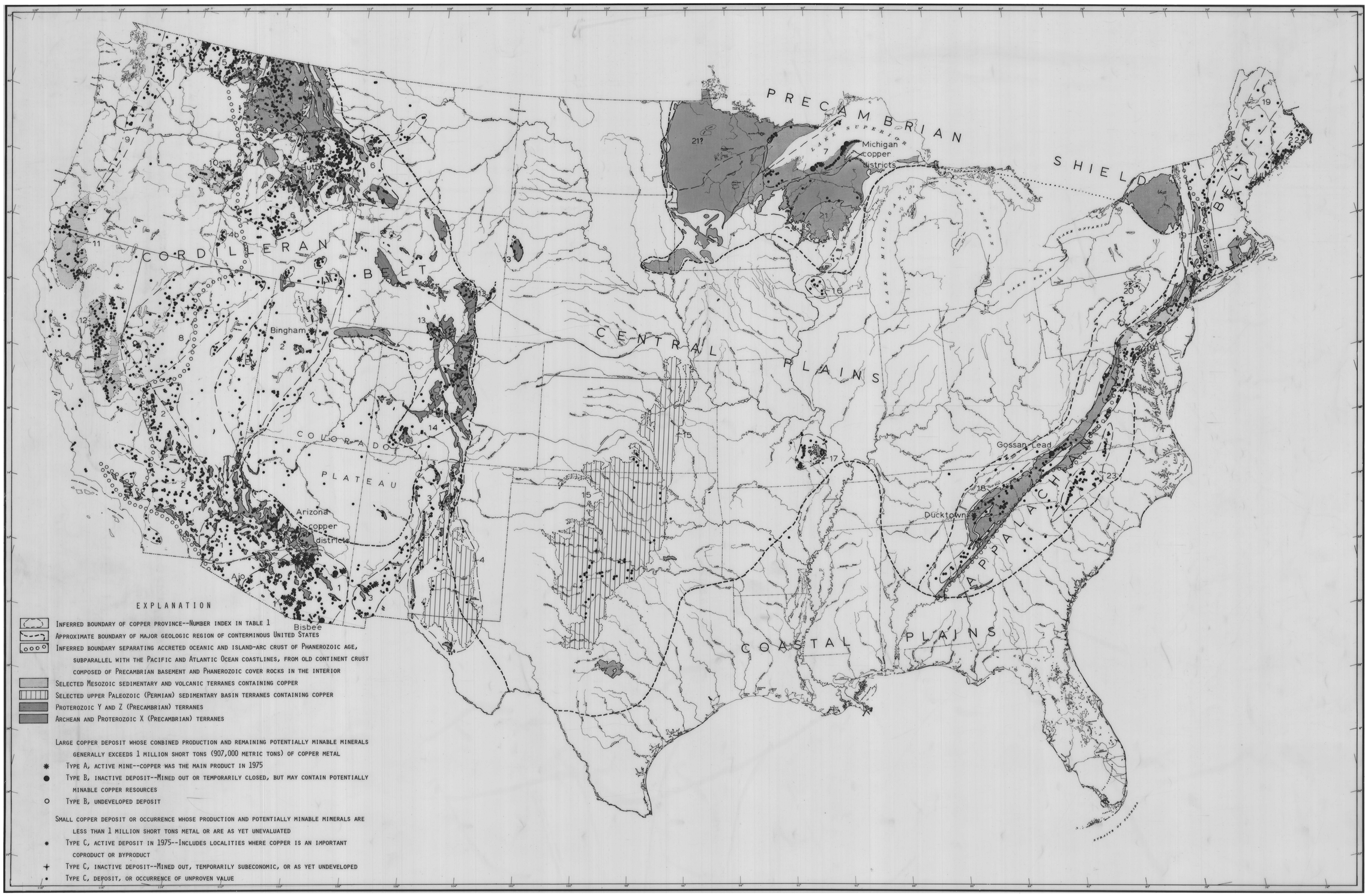
TOOKER-COPPER

PRELIMINARY MAP OF COPPER PROVINCES IN THE CONTERMINOUS UNITED STATES

By

Edwin W. Tooker

1980



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

INTRODUCTION

The map shown areas, called provinces, that are defined mainly by the location of groups of deposits and subeconomic occurrences of mineral materials containing copper, a metal which has long been of critical importance to industrial nations because of its physical and mechanical properties. The United States is the world's largest producer (23 percent in 1975). More than half of the apparent consumption of 1.7 million short tons (1.5 million metric tons) in 1975, the base year for this survey, was used by the electrical industry; the remainder was consumed by construction, household utensil, military, decorative arts, jewelry, and coinage industries (Schroeder, 1976). Substitutes for copper are unsatisfactory for many uses, and some copper is dissipated in use and cannot be recovered or is not economic to recover as scrap. Eighty percent of the copper used was derived from primary mine production, the remainder from secondary (reclaimed scrap), industry stocks, and net import sources, according to U.S. Bureau of Mines (1979) information.

The porphyry copper deposit is the principal present domestic source of primary copper, but other geologic types of copper resources are mined and may be required more extensively in the future as porphyry deposits sources are depleted. D. P. Cox (oral commun., 1978) has estimated an amount of copper equivalent to about 1-1/3 average porphyry copper deposits (roughly 10 million short tons or 9 million metric tons) is consumed in the world each year and that 30 or 40 deposits or mines must be replaced by the year 2000 in order to satisfy long-term growth in demand. Thus, while copper seems to be abundant in geologic terms and is economically available, present domestic sources will, in the longer term, become depleted and new sources of copper will need to be identified and discovered.

All types of copper deposits therefore are of continuing critical importance for determining the nation's future copper supplies, and the main objective of the copper province map is to identify broad areas of search for potential future domestic resources of this metal. The copper province map shows the locations and relative sizes of known deposits and subeconomic occurrences, hence the comparative current economic importance of provinces. Areas of important (1975) mining activity as well as of former production are shown, and the geologic characteristics of the chief types of copper mineral concentrations as well as a preliminary assessment of anticipated resource potential for provinces are tabulated.

The main ore minerals of copper include the native metal, sulfide and sulfarsenide, oxide, and carbonate species. There is an additional large group of secondary copper minerals. Cox and others (1973, p. 168) have classified copper deposition into six major geologic types or environments: I, disseminations in intrusive granitoid porphyry bodies; II, disseminations and segregation in intrusive mafic and ultramafic rock complexes; III, stratabound massive sulfide bodies in volcanogenic sedimentary sequences; IV, vein and replacement deposits in sedimentary and igneous rocks; V, disseminations in sedimentary rocks; and VI, cavity and intergranular (native copper) fillings in coarse volcanic and sedimentary rocks. Proportionately, groups I and IV contribute more than 66 percent to domestic production, V about 25 percent, III 5 percent, and all of the rest together constitute less than 4 percent. Copper may be extracted from these deposits as a primary material, as well as a coproduct or byproduct from the mining of a diverse group of associated metals such as nickel, cobalt, gold, silver, lead, zinc, molybdenum, the platinum group, iron, uranium, and vanadium.

The map was compiled from published reports (Lindgren and Grey, 1976; Jones, 1965; Kinkel, 1967; Kinkel and others, 1968; Kinkel and Peterson, 1962; Kirkemo, 1964; Klevarsnasy, 1977; Maine Geol. Survey, 1958, 1959; Mining Mag., 1976; Nuechel and McKnight, 1964; Pearre and Calkins, 1957; Roberts, 1964; Schwartz and Prokopovich, 1956; Weissenborn, 1968; and White, 1976), records of copper resource specialists, and data from the Computerized Resource Information Bank (CRIB) of the U.S. Geological Survey. I am especially indebted to D. P. Cox for his many insights and refinements of the copper localities and provinces and particularly the distribution of potential copper resource materials. Geologic information used on the map is from the geologic map of the United States (King and Beikman, 1974). The rationale of province maps in an atlas series, of which this report is a part, and some of the technical terms and geologic concepts used in them are discussed and defined in a companion background report by Tooker (1978b).

DISTINGUISHING MAP FEATURES

The map shows the regional distribution of 23 copper provinces and tentative provinces in the conterminous United States. Provinces are considered to be favorable search areas in which local concentrations of copper are well above its average crustal abundance--about 30 parts per million (ppm) according to Parker (1967). As defined, provinces are areas that contain sporadic to densely populated groups and clustered groups of present or former primary, coproduct, or byproduct copper deposits and reported occurrences. Within a province, as defined, the metal generally occurs in distinctive geologic settings, although some overlaps or mixed geologic host environments are not uncommon because of changes of geologic conditions, possibly indicating some remobilization and redeposition of copper during geologic time. A tentative or queried province represents an incomplete 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 the broad definition of a province.

Boundaries of provinces may be based on one or a number of criteria. Where possible they 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 also enclose a region that is characterized by a favorable rock unit or a broadly favorable deposition region such as a sedimentary basin. A number of solitary and isolated localities are present which do not seem to fall into a regional geologic pattern and represent unknown anomalies. When areas containing such localities are studied and sampled systematically, the dispersion may correctly indicate little or no resource potential, or provide a clue that may result in discovery of a new copper resource. One of the purposes of this map is to identify such possibilities and narrow the search for new domestic areas that are geologically favorable for resource identification.

Copper deposits and occurrences have been classified on the map for purposes of comparison in the atlas into large and small sizes (Tooker, 1979b). A large deposit, as defined by Kinkel and Peterson (1962), is one whose production and remaining potentially minable copper ores aggregate more than 1 million short tons (907,000 metric tons) of contained metal. The copper in such a deposit would have been valued in 1978 at about $1.36 billion and contain the equivalent of about 40 percent of the apparent United States consumption that year, on the basis of U.S. Bureau of Mines (1979) information. Small deposits are defined as localities containing a known resource of less than 1 million short tons, or reported but undetermined amounts of copper.

Large deposits in the atlas are subdivided into active, inactive active producers in 1975 (type A) and those that for several reasons were inactive or are as yet undeveloped (type B) on the basis of U.S. Geological Survey (1975) data and (or) as reported in a world survey of major mines (Mining Mag., 1976). Type A, shown by a large star symbol, are the large producing deposits that were mined primarily, but not exclusively, for copper. Type B, large (circle symbol), former large productive deposits that (1) are now mined out, (2) are temporarily closed but contain an additional known but currently subeconomic resources, (3) are now currently small producers that may not have been recognized as significantly active in the survey, and, finally, (4) known but undeveloped deposits (large open dot) that contain minable future resources. The distinction between active and inactive large deposits provides a visual evaluation of the relative amount and location of past domestic copper production as compared with current (1975) productive areas.

Three classes of active and inactive type C deposits are shown on the map: (1) recognized small producers in 1975 (small star symbol) that in part include some localities from which coproduct or byproduct copper was produced and noted in the survey; (2) inactive deposits (small dot with superposed cross symbol) that were mined out or may contain additional potentially minable or subeconomic copper resources; and (3) former deposits or occurrences (dot symbol) of unproven value.

The distribution of copper localities shown on the map is the result of at least two levels of geologic control: as local concentrations in distinctive rock-forming environments whose boundaries may in some cases be shown; and as broader continent-wide distributions that may be considered within the context of new geologic theory. The following five major types suggested by Cox and others (1973) are based on depositional relationships with associated geologic units. The main types of deposits and occurrences within provinces are shown on table 1.

I, Porphyry and related types of ore deposits.--Porphyry copper deposits generally contain low-grade (less than 1 percent) concentrations of copper disseminated in highly fractured pluglike intrusive bodies. These commonly are light-colored, silica-rich intrusive rocks; less commonly they may be more mafic intrusive rocks. Hydrothermal alteration of intruded rocks is also generally present near such bodies and aids in their exploration (Lowell and Guilbert, 1970). These deposits may also contain byproduct molybdenum, gold, silver, lead, zinc, iron, and manganese.

II, Mafic intrusive rocks.--Copper and nickel sulfide segregations and discontinuous lenses and layers near the base of mafic (dark-colored) stratiform intrusive rocks (Wilson, 1969) commonly contain deposits or occurrences of copper. Although few of this type have yet become economic sources of copper in the conterminous United States, copper is a geologically available subeconomic resource, which is commonly associated with the coproduct metals nickel and cobalt.

III, Volcanogenic "massive sulfides".--Small undeformed lenticular high-grade stratiform sulfide deposits occur in volcanic lava and pyroclastic eugeosynclinal (deep ocean basin) sedimentary rocks. Minable copper minerals are generally associated with iron sulfide and sometimes associated with zinc and lead sulfides and silicate minerals. Ore minerals may also occur in highly altered volcanic rock as disseminations and in networks or swarms of veins, and in cavities in the lava layers, often intensely broken by later gravitational slumping.

IV, Sedimentary rock veins and replacements.--A large group of small irregular but high-grade copper vein or replacement deposits, as well as base-metal deposits containing copper as a byproduct, occur in sedimentary rocks of all geologic ages. The ore materials were mobilized, transported, and deposited by hydrothermal solutions, commonly spatially and genetically associated with plutonic rock bodies.

V, Disseminated sedimentary deposits.--Stratabound copper deposits are formed in at least three generally different geologic environments: (1) as disseminations, blebs, and veins of copper formed in laterally persistent beds of initially porous and sandy rocks characteristic of a shallow marine (or restricted basin environment; (2) laterally persistent thin copper enrichments formed in thin-bedded, impregnated layered deposits in tidal flats rich in organic material which host the precipitation and the absorption of metals, and (3) copper accumulations of irregular size, shape, and grade within locally chemically reactive parts of sedimentary rocks (such as black shales, sandstone with carbonaceous material or carbonate rocks) which came in contact with heated metal-bearing connate brine or meteoric ground waters.

On the continental scale there seems to be a broadly defined structural control over the concentration of copper in crustal rocks. Noble (1970) has discussed much of the evidence for this in detail, from which he concludes the subduction model of the plate tectonic hypothesis fails to explain. I believe, however, that the main constraint may be an incomplete understanding of plate tectonic process, and, in fact, on the basis of Noble's (1970) "conclusions and unresolved problems," and some very general observations of geological distributions from the atlas maps, the plate model is relevant for considering metal distribution.

Copper provinces seem to be closely identified with characteristic geologic environments and host rocks in the two main types of crustal plates shown in the map--structured oceanic and island-arc and old continental--as defined by Coleman (1978a, b). The oceanic and island-arc plate, which was added oid continental--as defined by Coleman (1978a, b). The oceanic and island-arc plate, which was added sequentially during Phanerozoic time to an older continent plate by gradual accretion along a subduction zone, contains a characteristic simple copper mineral assemblage emplaced in tectonically simple copper deposits. Sillitoe (1978) provides some of the finer details of the geology of porphyry copper deposition in the oceanic-type plate rocks of California. In contrast, provinces found on the old continent crust, which contains Precambrian basement rocks as well as Phanerozoic surface cover rocks, are characterized by a larger number of localities (including most type A and B deposits) that contain more complex mineral assemblages, and often in mixed geologic types and ages of deposits. Boundaries separating these two crustal types are inferred on the map for both the Cordilleran and Appalachian belts (Tooker, 1978b). Discussion about copper provinces listed in table 1 are based on their position and composition in this large-scale geologic context.

COPPER PROVINCES

Twenty-three copper provinces are located in all major geologic regions of the conterminous United States except the Coastal Plains. The provinces, as listed in table 1, are compared in terms of the variations in types of geologic concentrating environments and preliminary estimates of the potential resources contained or expected. The first six provinces are listed in approximate order of importance to domestic production in 1975, the rest are unordered. A heavy concentration of large deposits in the southwestern part of the Cordilleran belt, in Arizona and New Mexico, can be observed on the map. These deposits accounted for one-quarter of all United States mines listed in the international mining survey (Mining Mag., 1976), roughly 46 percent of 1977 production (Schroeder, 1976), which is a demonstration of the importance of copper mining to this part of the nation. Historically, most early production was from the Precambrian shield area of Michigan and the southern part of the Appalachian belt (Kinkel and Peterson, 1962). Copper has also been an important coproduct or byproduct of base- and precious-metal deposits in many regions.

A broad poorly defined arcuate zone along the western boundary of the old continent, from Montana and Idaho to Arizona and New Mexico, contains the major Cordilleran porphyry copper deposits as well as a number of hydrothermal vein and replacement deposits of coproduct or byproduct copper. Seven copper provinces in this belt contain more than thirty large type A, B, and starred type C deposits.

The region also contains other types of copper occurrences in sedimentary (some volcanogenic) stratiform disseminations and mafic rock segregations. Within an individual province, several geologic deposit types whose ages range widely may be present. Provinces 1, 2, 3 and 5--8 enclose irregular clusters of deposits and occurrences that seems to lie along nearly regularly spaced broad northeast-trending zones or bands in the Cordilleran belt, which are separated by small or sparsely populated occurrence areas. For the most part provinces are nearly coextensive with exposed (uplifted) northeast-trending bands of Precambrian basement rocks. Deposits and occurrences contained within provinces may be localized in rocks of widely ranging ages, from the Precambrian through the Phanerozoic. These coextensive bands seem to be overlain by the Snake River volcanic field (not shown) and interrupted by the Colorado Plateau; bands also seem to terminate westward in the broad zone along the interior old continent oceanic and island-arc boundary. Most large type A or B deposits in the Cordilleran region occur near the edges of old continent crust. Some provinces locally seem to project eastward beyond the Rocky Mountain front of the Cordilleran belt in areas where Precambrian basement rocks have been exposed.

Province 1, an area of major world copper enrichment, consists of two parts or subprovinces. The Arizona copper districts, centered on the Tucson region in south- central Arizona, contain the main domestic sources of copper--type A and B deposits. These are located in a geologic terrane containing mostly younger Proterozoic Y and Z (Precambrian) rocks exposed in a northeast-trending zone that is truncated on the north by the Colorado Plateau, but apparently extends southwest into Mexico. The less productive subprovince in west-central Arizona, in the Prescott region, contains large deposits and many more small deposits and occurrences located mostly in a geologic terrane of older Proterozoic X (Precambrian) rocks. This province terminates northward against the Plateau, and southward it seems to end along the continental crust boundary.

The boundaries of province 2 have been drawn somewhat arbitrarily in a region containing widely spaced outcrops of Precambrian rocks that seem to be related along a generally northeast-trending zone across the grain of major north-south-trending faults in the eastern Great Basin. The province is of great economic significance because it contains two type A as well as starred type C deposits.

Disseminated copper in sediments of the Belt Series (Precambrian) is one of the main largely unassessed subeconomic sources in province 3. These and other geologic types of small deposits and occurrences form a distinct concentration of localities in eastern Washington, northern Idaho, and northwestern Montana. They are separated from those located on the Butte (southwestern Montana) district in province 6, which contains at least three type A and B deposits. Province 6 has been projected eastward to include a number of allied occurrences in the northern Central Plains.

Deposits and occurrences of copper along the western border of the Cordilleran belt are typical of those found in oceanic and island-arc crust. They are similar in relative abundance and variety to those above in old continent rocks, and copper occurs mainly as massive sulfides sometimes associated with veins and disseminations. None of the deposits are in the Precambrian basement rocks of the craton, and most of the localities shown are subeconomic. The porphyry copper occurrences in province 9 are associated with the Cenozoic volcanic centers of the Cascade Mountains. Those explored to date are smaller than their old continent plate counterparts. Provinces 10 through 12 lie within Mesozoic volcanogenic copper sedimentary rock sequences that have been intruded by mafic and ultramafic rocks, and copper eugeosynclinal rock sequences that have been intruded by mafic and ultramafic rocks, and copper localization in provinces 11 and 12 seems to be closely related to major (subduction) fault structures (Albers, 1978).

Western Great Basin province 8 along the old continent boundary may be located partly in oceanic plate rock. Like other provinces that lie in this plate, it contains one future large (type B), but mostly type C copper deposits, and the geologic types are in part associated with overthrusted Precambrian rocks from the west. Even though no Precambrian rocks are exposed, and the plate tectonic setting is essentially east of the province, Hotchkiss and Peterman, 1978) support the theory that the now-covered old continent may have extended further west than shown. Province 8 may thus be considered a linear extension of province 6 in Idaho and Montana and represent a buried segment of the same zone of copper mineralisation.

The Colorado Plateau occurrence suit is locally broken only where deep erosion has exposed basement rocks; a northeast trend across the plateau containing very sparse copper occurrences seems to connect similar terranes of province 1 in western Arizona with province 13, which trends from the Laramie, Wyo., area to the Black Hills, S. Dak. The Colorado Front Range, province 14, lies along a similar parallel trend, the deposits in these provinces seem to be distributed along a major Precambrian structural system. Finally, province 3 along the Rio Grande trough in New Mexico, which contains two type A deposits, also fits into the broad regional northeast pattern of associated faulted Precambrian terranes and copper deposits and occurrences. The province is overlapped eastward in the Central Plains by province 4 in which copper occurrences are disseminated in Paleozoic sedimentary rocks very similar to those in province 15.

Copper deposits and occurrences are also localized along the eastern margin of the old continent crust in the Appalachian belt. Province 18 (Southern Appalachians) contains two of the large (type A and B) deposits and many small deposits and occurrences. Copper occurrences in province 19 (Northern Appalachians) are closely associated with Precambrian and early Paleozoic igneous and metamorphic rocks in a discontinuous belt from Virginia to Massachusetts, in which copper occurs mainly as massive sulfides (Ducktown and Gossan Lead) and related disseminations and veins in host rocks and shear zones, and in Neozoic sandstone and shale adjacent to mafic intrusives. Small copper-molybdenum porphyry occurrences also have been located in the Appalachian belt.

The Precambrian shield, province 7, in the exposed core of the old continent plate, contains important copper concentrations. The region may also contain a potentially large but unevaluated copper resource in province 21. Province 7, which includes the venerable Michigan copper district, contains one type A and three type B deposits and many small deposits. The principal resource, native copper, occurs mainly in stratiform bodies in permeable conglomerate and basaltic rocks. The potential in province 21 for stratiform (massive sulfide) coproduct copper associated with greenstone bodies, similar to those which have been found in northern Wisconsin, remains to be demonstrated. Disseminations and segregations containing large amounts of copper and nickel occur in mafic rocks at the base of the Duluth Complex. No comparable copper occurrences have been reported in shield rocks in the Adirondack Mountains, province 19.

Copper in locked in the Central Plains mainly in stratabound deposits such as those in late Paleozoic redbeds in provinces 4 and 13, and as coproducts of base-metal deposits of the Mississippi Valley type. The latter are provinces 16 and 17 in southeastern Missouri and the Illinois-Kentucky (upper Mississippi Valley) districts. Replacement and vein minerals in Missouri occur in early Paleozoic dolomite and sandstone and shale adjacent to igneous rocks.

The copper in oceanic crustal rocks in the eastern part of the Appalachian belt seems to have some geologic characteristics in common with those in the Cordilleran belt. In the Canadian belt, the coastal province, province 22 are localized in eugeosynclinal sediments and closely associated with mafic volcanogenic rocks. Similar deposits occur in the Appalachian belt in province 23 of Maine and Vermont. Gold-quartz veins in mafic volcanic rocks, somewhat resembling those of the Sierran foothills province, occur in province 20.

In contrast to the provinces and data that copper concentrations, both economic and subeconomic, are areally restricted to distinct zones or belts of favorable rocks in the old continent crust and provide resource targets that will require additional geologic study.

REFERENCES CITED

Albers, J. P., 1978, Tectonism and metallogenesis in California [abs.]: Circum-Pacific Energy and Mineral Resource Conference, 2d, Honolulu, July 30-August 4, 1978, 1 p. (in press).

Cox, D. P., Lindahl, P. C., Grey, G. G., Klein, D. P., Richmond, G. M., and Fletcher, Michael, 1973, Copper, in United States mineral resources: U.S. Geological Survey Professional Paper 820, p. 163-190.

Johnson, K. S., and Grey, B. L., eds., 1976, Stratiform copper deposits of the mid-continental region, a symposium: Oklahoma Geological Survey Circular 77, 99 p.

Jones, W. R., 1965, Copper, in Mineral and water resources of New Mexico: U.S. Congress, 89th, 1st Session, Senate Committee Interior and Insular Affairs, Committee Print, p. 160-176.

King, P. B., and Beikman, H. M., 1974, Geologic map of the United States: U.S. Geological Survey Map, scale 1:2,500,000.

Kinkel, A. R., Jr., 1967, Copper, in Mineral and water resources of Missouri: U.S. Congress, 90th, 1st session, Senate Document 19, p. 63-68.

Kinkel, A. R., Jr., Feitler, S. A., and Hobbs, R. G., 1968, Copper and sulfur, in Mineral resources of the Appalachian region: U.S. Geological Survey Professional Paper 580, p. 377-383.

Kinkel, A. R., Jr., and Peterson, N. P., 1962, Copper in the United States: U.S. Geological Survey Mineral Investigations Resource Map MR-3, scale 1:3,168,000.

Kirkemo, Harold, 1964, Metallic mineral resources--Copper, in Mineral and water resources of Nevada: U.S. Congress, 88th, 2d session, Senate Document 87, p. 81-87.

Kistler, R. W., and Peterman, Z. E., 1978, Reconstruction of crustal blocks of California on the basis of initial strontium isotopes in subduction-related granitic rocks: U.S. Geological Survey Professional Paper 1071, 17 p.

Klevarsnasy, Gene, 1977, The role of the Precambrian igneous basement in the formation of stratabound lead-zinc-copper deposits in southeast Missouri: Economic Geology, v. 72, p. 433-442.

Lowell, J. D., and Guilbert, J. M., 1970, Lateral and vertical alteration-mineralization zoning in porphyry ore deposits: Economic Geology, v. 65, p. 373-408.

Maine Geological Survey, 1958, Metal mines and prospects: Maine Geological Survey, Minerals Resources Index, no. 3, 53 p.

_____1959, Mineral resources reference map serial N.H.N.B.W. 1, scale 1:250,000.

Mining Magazine, 1976, International mining survey, table B--1,126 mines accounting for 90 percent of annual output other than coal: v. 135, p. 221.

Neuchel, V. S., and McKnight, E. T., 1964, Map showing metallic mineral deposits of Missouri: U.S. Geological Survey Missouri Basin Studies No. 5, scale 1:1,200,000.

Noble, J. A., 1976, Metallogenetic provinces of the Cordillera of western North and South America: Mineralium Deposita, v. 5, p. 235-251.

Parker, R. L., 1967, Composition of the earth's crust, Chapter D of Fletscher, Michael, ed., Data of geochemistry (6th edition): U.S. Geological Survey Professional Paper 440-D, 19 p.

Pearre, W. C., and Calkins, J. A., 1957, Mineral deposits and occurrences in Vermont, exclusive of clay, sand, and gravel: Vermont Geological Survey Publication 7, 107 p., 1 map, scale 1:500,000.

Roberts, R. J., 1964, Metallic mineral resources--Copper, in Mineral and water resources of Utah: U.S. Congress, 88th, 2d Session, Committee Print, p. 75-83.

Schwartz, G. M., 1959, Geology of the San Manuel copper deposit, Arizona: U.S. Geological Survey Bulletin 1057, p. 1-18.

Schwartz, G. M., and Prokopovich, Nikola, 1956, Map of mineral resources of Minnesota, 1956, scale 1:1,000,000.

Tooker, E. W., 1979a, Metal provinces and plate tectonics in the conterminous United States, in Ridge, J. D., ed., Papers on mineral deposits of western North America: Nevada Bureau of Mines and Geology Report 33, p. 31-38.

_____1979b, Background information to accompany 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, Copper, in Mineral commodity summaries 1979: U.S. Bureau of Mines, p. 42-43.

Weissenborn, A. E., 1968, Copper, in Mineral and water resources of Montana: U.S. Congress, 90th, 2d Session, Senate Document 94, p. 82-84.

White, W. S., 1976, Copper, in Mineral and water resources of Wisconsin: U.S. Congress, 94th, 2d Session, Senate Committee Print, p. 107-227.

Wilson, H. D. B., 1969, ed., Magmatic ore deposits, a symposium (Stanford University, Stanford, California): Economic Geology, Manual 4, 364 p.

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 (in press), available free of charge from the U.S. Geological Survey, Branch of Distribution, 1200 Eads St., Arlington, VA 22202.

Table 1.--Locations, type of deposits, estimates of resource potential, and status of resource information of copper provinces

No.	Province location: State	Province location: Area	Geologic types of deposits[1]	Preliminary estimates of resource potential: High	Medium	Low	Status of geologic resource information: Adequate	Insufficient
1	Arizona and California	Southern borderland	I, IV, V(a)	X	--	--	--	X
2	Utah, Nevada, and California	Great Basin	I, IV, V(a) and (c)	X	--	--	--	X
3	New Mexico	West Central	I, III, IV	--	X	--	--	X
4	Do.	East Central	V(b) and (c)	--	X	--	--	X
5	Idaho, Montana and Wyoming	Northern Rocky Mountains	I, IV, V(a)	--	X	--	--	X
6	Do	Butte area	I, IV, V	X	--	--	--	X
7	Michigan	Upper Peninsula (Michigan Cu district)	V(a)	X	--	--	X	--
8	Nevada	Western Basin and Range	I, III, IV	--	X	--	--	X
9	Washington and Oregon	Cascade Mountains	I, IV, V(a)	--	X	--	--	X
10	Oregon and Idaho	John Day-Cuddy Mountains	II, III, IV	--	--	X	--	X
11	Oregon and California	Klamath Mountains	II, III, IV	--	--	X	--	X
12	California	Sierra Foothills	II, III, IV	--	--	X	--	X
13	Wyoming and South Dakota	Laramie, Wyoming-Black Hills, South Dakota	IV	--	--	X	--	X
14	Colorado	Front Range of Rocky Mountains	III, IV	--	--	X	X	--
15	Kansas, Oklahoma, and Texas	Great Plains	V(b) and (c)	--	X	--	--	X
16	Wisconsin and Illinois	Upper Mississippi Valley lead district	IV	X	--	--	--	X
17	Missouri	Lead district, southeast Missouri	IV	--	--	X	X	--
18	Alabama, Georgia, North Carolina, Virginia, Maryland, Tennessee	Southern Appalachian Mountains	III, IV	--	X	--	--	X
19	Pennsylvania, New Jersey, New York, New England	Northern Appalachian Mountains	II, III, IV	--	X	--	--	X
20	Pennsylvania	Redbed Cu district	V(a)	--	--	X	--	X
21	Minnesota, Wisconsin, and Michigan	Lake Superior Precambrian Shield	III	X	--	--	--	X
22	Maine	Coastal	III and IV	--	X	--	--	X
23	Virginia and North Carolina	Piedmont	IV	--	--	X	--	X

[1]Main types of deposits (Cox and others, 1973):

Type	Deposit characteristics	Type of vein or deposit
I	Silicic porphyry intrusion	Disseminated (low grade)
II	Mafic intrusive rocks	Disseminated (low grade)
III	Stratiform in volcanogenic sediments	Massive sulfide (medium and high grade)
IV	Hydrothermal in sedimentary (or metasedimentary) rock	Vein or replacement manto (high grade)
V	Stratabound in sedimentary (volcanogenic or metasedimentary) rock	Disseminated (low to high grade) (a) arenaceous (includes permeable conglomerate and basalt) (b) sabkha (shale) (c) channel zones

[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.