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

PRELIMINARY MAP OF TIN OCCURRENCE AREAS IN THE CONTERMINOUS UNITED STATES

By

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INTRODUCTION

The tin map shows the location of known domestic resources of this metal, which because of its special properties has important political and strategic significance for the nation. Most of the non-Communist world's tin is produced in developing nations of southeast Asia, while most of the tin is consumed by the major industrialized nations. The United States consumed about 20 percent of world production in 1977, mostly for tin-plate, alloys, electrical and automotive manufacturers, and industrial chemicals. The metal is nontoxic, has a low melting point, a low coefficient of friction, when melted has good fluidity and wetting characteristics, and forms an oxide coating that is inert to weak acids, bases, and the atmosphere. Other materials can be used as substitutes for tin, but with reduced efficiency; some substitutes are equally critical materials and import dependent. About 75 percent of the tin used in 1978 was derived from recycled scrap. Only a small amount (<100 metric tons) was produced domestically from mine production, and about 75 percent of the tin was imported, mostly from Malaysia, Indonesia, Thailand, and Bolivia (data from U.S. Bur. Mines, 1979). Hartz (1978) predicts a probable future growth rate of 5.4 percent annually through the year 2000. Because the United States must compete with other developed nations for such resources, this map was prepared to reexamine potential domestic source areas (whether economic or subeconomic), and to locate those geologically favorable target areas in the conterminous United States where further geologic studies may result, ultimately, in the recognition of tin provinces comparable with those for other metals.

The map was compiled from published reports (Killleen and Newman, 1965; Sainsbury, 1966; Sainsbury and Jahns, 1965; Sainsbury and others, 1970; Hatte, 1975; Lindsey, 1977; and Lindsey and Osmonson, 1978). Occurrence area boundaries were drawn on the basis of geologic map information (King and Beikman, 1974) and discussions with Geological Survey regional resource experts. Some of the resource and geologic technical terms and concepts used here and elsewhere in the atlas of some metal and nonmetal provinces, of which this map is a part, are defined and discussed in a background report by Tooker (1979).

DISTINGUISHING MAP FEATURES

This map shows the distribution of known localities containing occurrences of tin or areas that contain, or are expected to contain, locally anomalous concentrations of tin. An occurrence area on the map contains sporadic or clustered tin localities that lie in a geologic environment generally considered broadly favorable for tin enrichment; no distinction as to economic or subeconomic character is implied. Occurrence area boundaries are indefinite, but where possible, they enclose regions of favorable geologic terranes. For example, a boundary may enclose a region that includes a number of granitic intrusive or extrusive rock bodies where tin is locally concentrated in amounts well above its crustal background values of 2 to 3 ppm (parts per million). In some places boundaries have been drawn arbitrarily, including broad areas between localities where no geologic characteristics have been included, suggesting broadly favorable regions in which tin may not yet have been reported. A number of isolated localities on the map that now do not seem to fall into a local or regional geologic pattern may be stray occurrences having little if any resource potential, but they may be clues to new occurrence areas, which can only be proved by systematic geologic study. Recent geologic mapping and geochemical sampling in the western United States have indicated subeconomic analogues of productive lode tin deposits elsewhere in the world. This suggests that these localities should be studied and sampled systematically for their resource potential, lest an occurrence be regarded as having insignificant resource value or remain only an unrecognized clue to a more extensive undiscovered tin resource. The occurrence map is intended to identify areas where the search for tin might most profitably be initiated.

Tin localities have been classified on this map, in conformity with other maps of the atlas series (Tooker, 1979), into large and small deposits and occurrences. The importance of any commodity for a given region is, in part, based on its past or anticipated production. The main domestic source of tin in the conterminous United States is as a byproduct of molybdenum production at the Climax mine in Colorado. We estimate that the Climax mine may be capable of eventually producing 3,000 metric tons of tin, and we use this value to define a large domestic tin deposit. A deposit of this size would be valued at more that $50 million and represent only about 5 percent of the apparent consumption of tin by the United States in 1978 (U.S. Bur. Mines, 1979).

On the atlas series of maps, large deposits are subdivided into type A, those which were active producers in 1975, the base year of the atlas, and type B, former large producers that might be considered inactive (temporarily out of production, mined out, or may have been potential as a future source). Climax is the prototype and only large (type A) deposit recognized to date; there are no known type B tin deposits, possibly because our knowledge about the commodity in the conterminous United States is incomplete. The small active and inactive deposits and occurrences that constitute tin range in size from unknown or undetermined up to 3,000 metric tons. These type C localities, which are probably mostly subeconomic occurrences, comprise the remaining localities plotted on the map.

Tin is recovered from several types of lode and placer deposits, some of which have domestic counterparts that have been located on the map. The metal is preferentially concentrated by magmatic differentiation processes and shows a world-wide affinity for granitic rocks or their extrusive equivalents. Some greisens (intensively altered granite) which contain between 0.3 and 0.4 percent tin in disseminated cassiterite are presently being mined in Australia. Cassiterite (SnO$_2$) is the most important tin mineral, although small amounts of tin are recovered from tin-sulfide minerals such as stannite, cylindrite, and teallite. The metal has been produced from various types of lode deposits, some of which occur in the United States. The most common are: (1) pegmatites, generally associated with granitic rocks; (2) pneumatolytic-hydrothermal replacements and fissure fillings in country rock adjacent to or overlying biotite and (or) muscovite granite (often associated with peripheral zones containing tungsten, silver, and base metals); (3) subvolcanic tin-silver deposits such as those in Bolivia; (4) contact metamorphic skarn deposits near granite and associated with base metals, beryllium, and fluorine; (5) disseminated cassiterite in greisen deposits; (6) Mexican-type tin deposits in which cassiterite and wood tin occur in vein fracture fillings in Tertiary rhyolite, and as disseminated cassiterite in volcanic breccia; and (7) tin-bearing massive sulfide deposits such as those at the Sullivan and Kidd Creek mines in Canada.

Most of the world's tin is produced from placer deposits. Because cassiterite is both heavy and chemically resistant, it is concentrated in residual placers that form over or adjacent to bedrock source areas where weathering and erosional processes remove lighter rock materials and gravity assists in downslope movement of heavy minerals released by weathering to form eluvial placers. The richest placers are found in stream deposits where flowing water has concentrated heavy minerals generally derived from residual and (or) eluvial placers. Finally, ocean beach sands may also contain placer accumulations of tin such as those mined offshore in Indonesia and Thailand. No extensive placer deposits have been found in the conterminous United States thus far.

TIN OCCURRENCE AREAS

In spite of limited domestic production, tin is known to occur, subeconomically at least, in a number of places in the conterminous United States. At the present time the only significant stockpile of tin available to the United States is about 50,000 metric tons in the outside the conterminous United States as Alaska. Tin areas have been identified on this map and are indexed in table 1 as to the main geologic types of occurrences and their estimated resource potential. Reports by Killeen and Newman (1965) and Sainsbury and others (1970) describe many of the occurrences shown on the map. None of these areas are adequately known geologically to evaluate their possible tin resources. The data used in preparing the present map offers little encouragement for obtaining domestic self-sufficiency, but does not preclude the possibility that more tin may be found if favorable geologic terranes are systematically investigated.

The Cordilleran belt of western United States is considered to be the most favorable area for finding undiscovered tin resources. This area is part of the North American tin belt which extends from Alaska, through western Canada, to Mexico (Sainsbury and others, 1970). For most of the belt's 8,000-km length, however, tin occurrences are extremely dispersed, and many are of little more than mineralogical interest. Most geologists would hesitate to call the entire belt a tin province. Metal provinces are traditionally considered in terms of production figures; however, because much tin is a product of secondary concentrations (placer deposits) resulting from weathering of subeconomic low-grade lode deposits, a high production history may well reflect favorable past climatic conditions rather than primary crustal concentration levels. This is well exemplified by Malaysia which produces about 25 percent of the world's primary tin, but where less than 5 percent of the tin production is derived from lode deposits.

Area 1 includes the Front Range mineral belt of Colorado. In addition to the Climax stock, this region includes a number of molybdenum deposits containing late magmatic or early hydrothermal stage metals, such as tin, tungsten, uranium, thorium, columbium, and tantalum, that are associated with middle Tertiary (Cenozoic) silicic or other highly differentiated igneous rocks, or are present in adjacent skarns. These deposits should be examined for their byproduct tin, as well as their potential for other metals.

The possibility of economic Mexican-type deposits in New Mexico, Arizona, Utah, and Nevada, but particularly in area 2, needs a more thorough investigation because the geologic environment of Mexican-type tin deposits extends into this region. For the most part, tin occurrences in Cenozoic volcanic rocks are sparse, subeconomic, and of little immediate interest. Exceptions to this generalization do occur along rhyolite flow banding, because the volume of tin minerals in the fractures is small and economic mining seems unfeasible. Production of tin from these deposits has been limited to small placer operations which have produced a few hundred tons of tin each, such as in the Black Range, New Mexico. The recognition of disseminated low-grade cassiterite tin (on the order of tenths of a percent) in exceedingly large volumes (hundreds of thousands of metric tons) within funnel-shaped breccia pipes in Mexico (Pan, 1975) suggests the feasibility for large-scale bulk mining of such deposits, if located.

The two largest tin-producing mines in North America are at Sullivan (British Columbia) and Kidd Creek (Ontario) in Canada. Until recently, massive sulfide deposits have not been evaluated for their tin potential. It is quite possible that there may be massive sulfide deposits presently being mined in the conterminous United States whose tin potential has not yet been recognized. The presence of a Paleozoic subvolcanic cassiterite-sulfide deposit at Mount Pleasant (New Brunswick) suggests, for example, that a similar geologic terrane in coastal Maine should be considered for its tin resource potential.

The Boulder Mountains polymetallic tin province in central Idaho (area 4) has recently been defined by Tschanz and others (1974). These tin-bearing silver-base-metal veins cannot, at present, be economically beneficiated for tin. They do, however, resemble silver-tin-base-metal deposits in Bolivia, where the veins grade downward into productive cassiterite-bearing lodes. In Bolivia, as well as in Idaho, the tin-silver occurrences are related to small Cenozoic stocks. Careful evaluation of the polymetallic province in Idaho as a future source of tin therefore seems warranted.

Pegmatites associated with greisens occur in all occurrence areas but are virtually the only type found in the Appalachian belt (in areas 8, 9, and 10), in the uplifted Precambrian terranes of the Black Hills, South Dakota (area 6), and St. Francois Mountains of Missouri (area 7) in the Central Plains region.

The sparse tin occurrence data are insufficient as yet to define geologic provinces in which this metal has been concentrated. Whether this map shows the real tin distribution or represents our incomplete assessment can only be resolved by more systematic geologic mapping and geochemical sampling. The available data suggest that the metal has been concentrated preferentially along previously recognized broad northeast-trending Cordilleran and Appalachian belt zones, along which other metals also occur (Tooker, 1978, 1979; Noble, 1970). These same zones are the locale for exposures of uplifted basement rocks (King, 1976) and Phanerozoic intrusive bodies (King and Beikman, 1974; 1978). The most prominent alinements along such northeast-trending zones are delineated by area 4, areas 1 and 2, and areas 8, 9, and 10. Sainsbury and others (1970, p. 139) note that in the western United States tin deposits or tin minerals are generally found wherever Precambrian intrusive rocks of granitic composition are exposed. Precambrian crustal rocks may have served as a source of tin that was remobilized by highly differentiated Cenozoic intrusive igneous rocks.

REFERENCES CITED

Harris, K. L., 1978, Tin: Mineral Commodity Profiles 16, U.S. Department of the Interior, Bureau of Mines, 17 p.
Killeen, P. G., and Newman, W. L., 1965, Tin in the United States: U.S. Geological Survey Mineral Resources Map MR-44, scale 1:3,168,000.
King, P. B., 1976, Precambrian geology of the United States; an explanatory text to accompany the geologic map of the United States: U.S. Geological Survey Professional Paper 902, 85 p.
King, P. B., and Beikman, H. M., 1974, Geologic map of the United States: U.S. Geological Survey Map, scale 1:2,500,000.
_____1978, The Cenozoic rocks, a discussion to accompany the geologic map of the United States: U.S. Geological Survey Professional Paper 904, 82 p.
Lindsey, D. A., 1977, Epithermal beryllium deposits in water-laid tuff, western Utah: Economic Geology, v. 72, no. 2, p. 219-232.
Lindsey, D. A., and Osmonson, L. M., 1978, Mineral potential of altered rocks near Niwot Mountain, Wah Wah Range, Western Utah: U.S. Geological Survey Open-File Report 78-114, 19 p.
Noble, J. A., 1970, Metal provinces of the western United States: Geological Society of America, v. 81, no. 6, p. 1667-1674.
Pan, T. S., 1975, The genesis of the Mexican type tin deposits in acid volcanic rocks: Dissertation Abstracts International 9, the Sciences and Engineering, v. 35, no. 7, p. 3394B-3395B.
Hatte, J. C., 1975, Tin, in Mineral and water resources of South Dakota: U.S. Congress, 94th, 1st Session, Committee Print, p. 103-104.
Sainsbury, C. L., 1966, Tin, in Mineral and water resources of Washington: U.S. Congress, 89th, 2d Session, Committee on Interior and Insular Affairs, Committee Print, p. 145-147.
Sainsbury, C. L., and Jahns, R. H., 1965, Tin, in Mineral and water resources of New Mexico: U.S. Congress, 89th, 1st Session, Senate Committee on Interior and Insular Affairs, Committee Print (New Mexico Bureau of Mines and Mineral Resources Bulletin 87), p. 237-240.
Sainsbury, C. L., Mulligan, R. R., and Smith, W. C., 1970, The Circum-Pacific "tin belt" in North America, in A second technical conference on Tin, Bangkok, 1969, volume I: London, International Tin Council, p. 123-148.
Tooker, E. W., 1978, A plate tectonic setting for metal provinces in the conterminous United States: Abstracts with Programs, Geological Society of America, v. 10, no. 5, p. 230.
_____1979, Background information to accompany the atlas of some metal and nonmetal mineral provinces in the conterminous United States: U.S. Geological Survey Circular 792 (in press).
Tschanz, C. M., Ridlegaard, T. H., Seeland, D. A., Van Noy, R. M., Ridenour, James, Zilka, N. T., Federspiel, F. E., Evans, K. V., Tschek, E. T., and McMahon, A. B., 1974, Mineral resources of the eastern part of the Sawtooth National Recreation Area, Custer and Blaine Counties, Idaho, with a section on Aeromagnetic survey and tentative interpretation by Mabey, D. R., and Tschanz, C. M., and sections on Electromagnetic survey by Frischknecht, F. C.: U.S. Geological Survey Open-File Report, pt. I.
U.S. Bureau of Mines, 1979, Tin, in Mineral commodity summaries, 1979: p. 168-169.

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.

Table 1.--*Location, types of deposits, estimates of resource potential and status of resource information about tin provinces in the conterminous United States*

Province			Main types of deposits[1/]	Preliminary estimates of resource potential[2/]			Status of geologic resource information	
No.	State	Area		High	Medium	Low	Adequate	Insufficient
1	Colorado	Front Range mineral belt (Climax)	I and II	--	X	--	--	X
2	New Mexico	Rio Grande rift (Black Range)	I, II, III, V, and VI	--	--	X	--	X
3	Washington	Northern border, scattered	I, II, and VI	--	--	X	--	X
4	Montana and Idaho	Butte, Lemhi County, and Boulder Mountains	II, III, and VI	--	--	X	--	X
5	California	Southwest (Gorman-Pala)	I, II, III, IV, and VI	--	--	X	--	X
6	South Dakota	Black Hills	I	--	--	X	--	X
7	Missouri	St. Francois Mountains	I and II	--	--	X	--	X
8	Alabama	Rockford	I	--	--	X	--	X
9	North Carolina, South Carolina, and Virginia	Piedmont crystalline, Southern Appalachian Mountains	I, II, and VI	--	--	X	--	X
10	New England	Androscoggin River and pegmatite region and scattered localities	I	--	--	X	--	X

1/Index to types of deposits: Source: Killeen and Newman (1965); Sainsbury and others (1970)

I Pegmatite
II Pneumatolytic-hydrothermal replacement and vein deposits (includes greisen deposits)
III Subvolcanic (Ag-Sn)--no known deposits but geologic environment considered favorable
IV Contact metamorphic--tactites
V Mexican-type deposits
VI Placer (residual, eluvial and alluvial)

2/A high estimate indicates the presence or expectation of more than one large (type A or B) deposits; a low estimate indicates presence of type C deposits or occurrences only.