U.S. GEOLOGICAL SURVEY CIRCULAR 930-J

International Strategic Minerals Inventory Summary Report—Tin

Prepared as a cooperative effort among earth-science and mineral-resource agencies of Australia, Canada, the Federal Republic of Germany, the Republic of South Africa, the United Kingdom, and the United States of America

Geologic Time Scale

Age			Million years before present
Holocene	Quaternary	CENOZOIC	0.01
Pleistocene	Quaternary	CENOZOIC	2
Pliocene	Tertiary	CENOZOIC	5
Miocene	Tertiary	CENOZOIC	24
Oligocene	Tertiary	CENOZOIC	38
Eocene	Tertiary	CENOZOIC	55
Paleocene	Tertiary	CENOZOIC	63
Late Cretaceous	Cretaceous	MESOZOIC	96
Early Cretaceous	Cretaceous	MESOZOIC	138
Jurassic		MESOZOIC	205
Triassic		MESOZOIC	~240
Permian		PALEOZOIC	290
Pennsylvanian	Carboniferous	PALEOZOIC	~330
Mississippian	Carboniferous	PALEOZOIC	360
Devonian		PALEOZOIC	410
Silurian		PALEOZOIC	435
Ordovician		PALEOZOIC	500
Cambrian		PALEOZOIC	~570
PRECAMBRIAN	Late Proterozoic	PROTEROZOIC	900
PRECAMBRIAN	Middle Proterozoic	PROTEROZOIC	1600
PRECAMBRIAN	Early Proterozoic	PROTEROZOIC	2500
PRECAMBRIAN		ARCHEAN	

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By David M. Sutphin, Andrew E. Sabin, and Bruce L. Reed

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FOREWORD

Earth-science and mineral-resource agencies from several countries started the International Strategic Minerals Inventory to gather cooperatively information about major sources of strategic mineral raw materials. This circular summarizes inventory information about major deposits of tin, one of the mineral commodities selected for the inventory.

The report was prepared by David M. Sutphin and Bruce L. Reed of the U.S. Geological Survey (USGS) and Andrew E. Sabin of the U.S. Bureau of Mines (USBM). The tin inventory was compiled by Andrew E. Sabin (chief compiler); Ian S. McNaught, Australian Bureau of Mineral Resources, Geology and Geophysics; W. David Sinclair, Canadian Department of Energy, Mines and Resources (EMR), Geological Survey of Canada; and Ian Crocker, South African Department of Mineral and Energy Affairs, Geological Survey. Douglas Hartwick contributed information on the aspects of tin uses and supply. Additional contributions to the report were made by Antony B.T. Werner and Jan Zwartendyk, EMR, Mineral Policy Sector, and John H. DeYoung, Jr., USGS.

Director

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INTERNATIONAL STRATEGIC MINERALS INVENTORY SUMMARY REPORT

TIN

By David M. Sutphin,[1] Andrew E. Sabin,[2] and Bruce L. Reed[1]

Abstract

The International Strategic Minerals Inventory tin inventory contains records for 56 major tin deposits and districts in 21 countries. These countries accounted for 98 percent of the 10 million metric tons of tin produced in the period 1934–87. Tin is a good alloying metal and is generally nontoxic, and its chief uses are as tinplate for tin cans and as solder in electronics.

The 56 locations consist of 39 lode deposits and 17 placers and contain almost 7.5 million metric tons of tin in identified economic resources (R1E) and another 1.5 million metric tons of tin in other resource categories. Most of these resources are in major deposits that have been known for over a hundred years. Lode deposits account for 44 percent of the R1E and 87 percent of the resources in other categories. Placer deposits make up the remainder.

Low-income and middle-income countries, including Bolivia and Brazil and countries along the Southeast Asian Tin Belt such as Malaysia, Thailand, and Indonesia, account for 91 percent of the R1E resources of tin and for 61 percent of resources in other categories. The United States has less than 0.05 percent of the world's tin R1E in major deposits. Available data suggest that the Soviet Union may have about 4 percent of resources in this category.

The industrial market economy countries of the United States, Japan, Federal Republic of Germany, and the United Kingdom are major consumers of tin, whereas the major tin-producing countries generally consume little tin. The Soviet Union and China are both major producers and consumers of tin.

At the end of World War II, the four largest tin-producing countries (Bolivia, the Belgian Congo (Zaire), Nigeria, and Malaysia) produced over 80 percent of the world's tin. In 1986, the portion of production from the four largest producers (Malaysia, Brazil, Soviet Union, Indonesia) declined to about 55 percent, while the price of tin rose from about $1,500 to $18,000 per metric ton. In response to tin shortages during World War II, the United States began stockpiling refined tin metal from approximately 1946 to 1953 to ensure a strategic supply in the event of another war.

Since World War II, there have been six International Tin Agreements to maintain price and supply stability between tin producers and consumers. Artificially high prices set by the tin-producing members and a tin glut brought on by independent producers like Brazil caused the collapse of the world tin market in late 1985; the International Tin Council exhausted its credit to support the market price.

By the year 2025, Bolivia's underground lode mines will likely have insignificant production, as will those in the United Kingdom. Tin mines in the Southeast Asian Tin Belt will still be active. Brazil, which has risen from the eighth-ranked tin-producing country in 1982 to the largest producer in 1988, will likely be a major influence on world tin production well into the 21st century. The future mining activity of deposits presently inactive in Australia is impossible to predict.

PART I—OVERVIEW

INTRODUCTION

The reliability of future supplies of so-called strategic minerals is of concern to many nations. This widespread concern has led to duplication of effort in the gathering of information on the world's major sources of strategic mineral materials. With the aim of pooling such information, a cooperative program named International Strategic Minerals Inventory (ISMI) was started in 1981 by officials of the governments of the United States, Canada, and the Federal Republic of Germany. It was

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[1] U.S. Geological Survey.

[2] Formerly with the U.S. Bureau of Mines.

subsequently joined by the Republic of South Africa, Australia, and the United Kingdom.

The objective of ISMI reports is to make publicly available, in convenient form, nonproprietary data and characteristics of major deposits of strategic mineral commodities for policy considerations in regard to short-term, medium-term, and long-term world supply. This report provides a summary statement of the data compiled and an overview of the supply aspects of tin in a format designed to be of benefit to policy analysts and geologists. Knowledge of the geologic aspects of mineral resources is essential to discover and develop mineral deposits. However, technical, financial, and political decisions must be made and infrastructure must be constructed before ore can be mined and processed and the products transported to the consumer; the technical, financial, and political aspects of mineral-resource development are not specifically addressed in this report. This report addresses the primary stages in the supply process for tin and includes only peripheral considerations of tin demand.

The term "strategic minerals" is imprecise. It generally refers to mineral ore and derivative products that come largely or entirely from foreign sources, that are difficult to replace, and that are important to a nation's economy, in particular to its defense industry. Usually, the term implies a nation's perception of vulnerability to supply disruptions and of a need to safeguard its industries from the repercussions of a loss of supplies.

Because a mineral that is strategic to one country may not be strategic to another, no one list of strategic minerals can be prepared. The ISMI Working Group decided to commence with manganese, chromium, phosphate, and nickel studies. These studies plus studies of platinum-group metals, cobalt, titanium, graphite, and lithium have been published. Additional reports on tin (this report), tungsten, vanadium, and zirconium have been subsequently undertaken.

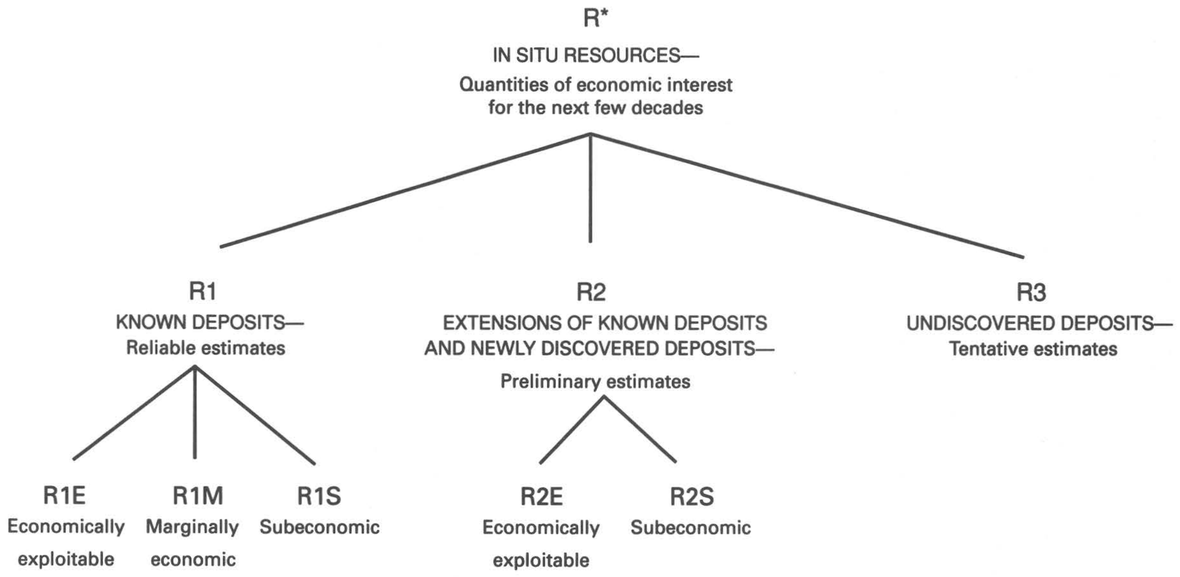
The data in the ISMI tin inventory were collected from October 1986 to May 1988. The report was submitted for review and publication in April 1989. The information used was the best available among the countries' agencies that contributed to this report. Those agencies were the U.S. Department of the Interior's Bureau of Mines and the Geological Survey; the Geological Survey of Canada and the Mineral Policy Sector of the Canadian Department of Energy, Mines and Resources; the Federal Institute for Geosciences and Natural Resources of the Federal Republic of Germany; the Geological Survey and the Minerals Bureau of the Department of Mineral and Energy Affairs of South Africa; the Bureau of Mineral Resources, Geology and Geophysics of the Australian Department of Primary Industries and Energy; and the British Geological Survey, a component of the Natural Environment Research Council.

Deposits (or districts) are selected for the inventory on the basis of *their present or expected future contribution to world supply*. Records for all deposits compiled by ISMI participants meet this general "major deposit" criterion and are included in the inventory.[3]

The ISMI record collection and this report on tin have adopted the international classification system for mineral resources recommended by the United Nations (U.N.) Group of Experts on Definitions and Terminology for Mineral Resources (United Nations Economic and Social Council, 1979; Schanz, 1980). The terms, definitions, and resource categories of this system were established in 1979 to facilitate international exchange of mineral-resource data; the Group of Experts sought a system that would be compatible with the several systems already in use in several countries. Figure 1 shows the U.N. resource classification used here. This report focuses on category R1, which covers reliable estimates of tonnages and grades of known deposits. The familiar term "reserves," which many would consider to be equivalent to r1E or R1E, has been interpreted inconsistently and thus has been deliberately avoided in the U.N. classification. It should be noted that generally, until a deposit has been extensively explored or mined, its size and grade are imperfectly defined. In many cases, deposit size will prove to be significantly larger, sometimes even several times larger, than was thought when the decision to mine was made. Experts having a sound knowledge of a deposit and its geologic setting might infer that the deposit extends beyond the bounds reliably established up to that time. Tonnage estimates for such inferred extensions fall into category R2. For major deposits, ISMI records show R2 estimates in the few cases for which they are readily available. Category R3, postulated but undiscovered resources, is not dealt with in this report.

Mining recovery from an ore body depends on individual conditions and may vary considerably, typically in the range of 75 to 90 percent for underground metal mining; that is, 10 to 25 percent of the in-place resources cannot be extracted. Recovery from placer mining is usually higher than that for underground

[3] No information is provided on deposits that were once significant but whose resources are now considered to be depleted.



***The capital "R" denotes resources *in situ*; a lower case "r" expresses the corresponding *recoverable* resources for each category and subcategory. Thus, r1E is the recoverable equivalent of R1E. This report deals only with R1 and R2, not with R3.**

FIGURE 1. United Nations resource categories used in this report (modified from Schanz, 1980, p. 313).

mining. Typically, placer mine recovery is above 90 percent and may approach 100 percent of in-place resources.

The World Bank economic classification of countries (World Bank, 1986, p. 180–181), which is based primarily on GNP (gross national product) per capita, has been used in this and other ISMI reports to illustrate distribution of resources and production according to economic groupings of countries. This classification was chosen because it relies primarily on objective economic criteria and does not contain political bloc labels that might not be perceived in the same manner by all countries.

USES AND SUPPLY ASPECTS

Tin is used almost exclusively as an intermediate input in the production of other products and metal alloys. It has a number of particularly useful physical properties that can significantly improve the production process and (or) alloys and other final products. Barry and Thwaites (1983, p.12–21) list many of the physical and chemical properties of tin.

Tin and tin-based products are generally nontoxic, are corrosion resistant, and have a good appearance. Tin's excellent wetting ability makes it an ideal metal to use as a coating of other metals. Tin alloys, generally tin-lead, tin-zinc, and tin-copper (bronze), offer properties depending on the alloy such as improved casting, greater hardness, and (or) a lower melting point than the single metal alone. In combination with aluminum, for example, tin offers important antifriction qualities desirable for engines and critical motor parts such as high-fatigue-strength bearings (Barry and Thwaites, 1983, p. 122–127, 151). Tin-based products are generally biodegradable and, when abandoned at the end of their useful life, will eventually oxidize and dissipate (Davis, 1985, p. 26–29).

Tin's single largest use is in electroplating, called "tinplate," followed by solder manufacture. It is used most extensively in the food packaging, electronics, and chemical industries followed by transportation, machinery, and construction. Recent years, however, have seen a gradual reduction in tin use for manufacture of tin cans due to the increased availability of less expensive alternatives such as aluminum and plastics for food and beverage containers. In the United States, the use of tin in solder is almost double that of tinplate (fig. 2). Nevertheless, tinplate is still considered by far the best container coating for many food products, and further decreases in demand are likely to be modest given the small percentage represented by the cost of tin in the

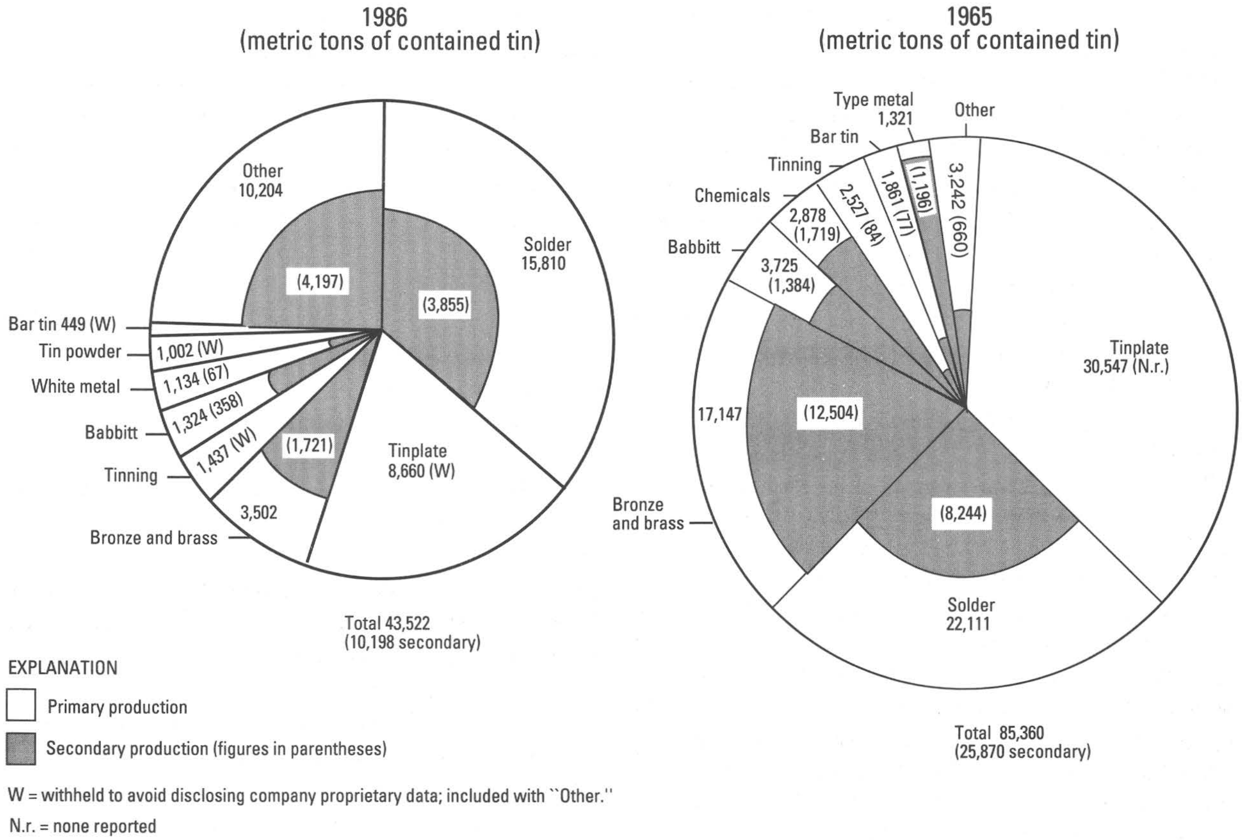


FIGURE 2. United States' tin consumption by finished product in 1986 and 1965 (Carlin, 1987, p. 966; U.S. Bureau of Mines, 1967, p. 327).

overall food-processing expense. Demand is a function of the relative cost of tinplate to aluminum, with tinplate's principal cost being due to the cost of the steel, not the tin.

Electronics, on the other hand, has seen a gradual increase in tin use as the world's demand for electronics products has increased and with it the demand for solder. While technological advances have succeeded in reducing the amount of solder needed per solder joint, the dramatic increase in the number of connections and the number of products that have electronic or computer components has ensured that tin's use in electronics will continue to grow for the foreseeable future.

Tin forms a wide variety of chemical compounds, and the utilization of tin chemicals in the plastics, glass, and ceramic industries, and in biocidal applications (for example, wood preservation, pesticides, antifouling paints), has increased over the past few years to where tin chemicals now account for about 13 percent of tin consumption today (Evans, 1988). The largest single use of tin in chemicals is use as a stabilizer for polyvinyl chloride (PVC) in the plastics industry; the tin prevents PVC from becoming yellow and brittle with prolonged exposure to sunlight or heat.

Tin deposits are not distributed uniformly around the world. Currently, the principal tin-producing regions are in Southeast Asia and Brazil. Moreover, of the 14 leading nonfuel minerals, tin has the greatest proportion of world production from low- and middle-income countries (Robertson, 1982, p. 2). As a result, the metal's principal consumers, industrial market economy countries, have been obliged to import the bulk of their tin. Unlike trade in other strategic metals, however, the relationship between tin-producing and -consuming nations has been gradually institutionalized in a series of international agreements made by consumers and producers whose stated purpose was to maintain price and supply stability in the world tin market. Until very recently, these agreements strongly influenced tin pricing on world markets. Moreover, they provided the vehicle for considerable political influence in the world tin trade. The most recent agreement ended in June 1989, coincident with the demise of the International Tin Council.

World tin supply has been influenced by several factors including (1) the International Tin Agreements (ITA's), (2) stockpiling of tin by the United States for strategic purposes, (3) disparate geographic and economic distribution of tin resources, (4) an increase in the number of government-owned and -operated mining and smelting concerns, (5) the Association of Tin Producing Countries, and (6) tin recycling.

The International Tin Agreements.—The ITA's were established in reaction to the collapse in world tin prices, largely brought about by the Great Depression. The agreements were set up to control tin supplies and to stabilize tin prices through a system of government-controlled quotas. As of 1989, there had been six agreements. ITA members came from two principal groups, producing and consuming nations, which collectively formed the International Tin Council (ITC). Most of the major producing and consuming countries were represented, but there were notable exceptions. The United States, the world's largest consumer, participated in only one agreement. Australia, Canada, and Great Britain, on the other hand, were party to all of the agreements, and West Germany participated since 1971 (Baldwin, 1983, p. 74–102). Brazil, which in the 1980's increased production by more than 300 percent to become the largest producer, however, was never a member. Producing countries were categorized in two groups: high-cost "underground" extractors and lower cost "placer" extractors. Bolivia was long the principal underground-mining country, with Malaysia, Indonesia, Thailand, and later Brazil as the most important placer-mining countries.

Early activities of ITC were most concerned with tin price and supply stability. However, the objectives of the organization gradually evolved to endorse activities that protected the incomes of the organizations' producers. To this end, tin purchases and sales were performed by the Buffer Stock Manager, whose function was to maintain a price floor through management of the buffer stock. As producing countries increased production in response to higher world prices, the ITC periodically imposed quotas to limit tin supply. This stimulated non-ITC producers to increase output to take advantage of artificially high prices. Export controls and the high price of tin further encouraged the smuggling of tin concentrates, particularly from Thailand.

By the late 1970's, the early cooperation of ITC members gradually gave way to frequently sharp differences between producing and consuming members. Consuming nations felt the organization was drifting from its original purpose of supply and price stability, whereas producers argued that their incomes were being eroded by inadequate tin prices and periodic sales by the United States from its strategic stockpile.

Despite the ITC's measures to restrict output, a tin glut emerged in 1983–85, because consumption remained stagnant while new, non-ITC producers such as Brazil emerged as major tin suppliers. To counter this development, the ITC's Buffer Stock Manager made large purchases of tin to support the price and to remove excess supplies. In October 1985, unable to finance further purchases, ITC buffer-stock activities ceased; the two main tin-trading markets, Kuala Lumpur and the London Metal Exchange, suspended tin trading, and the world price of tin collapsed to about half the previous level.

When tin trading at the London Metal Exchange resumed in June 1989, there was an increasing demand for tin, and the price climbed about $2,000 a ton and touched peaks not seen since before the market collapsed in October 1985. However, in late 1990, tin prices have again weakened, and the market has been impossible to forecast with any certainty.

The United States strategic tin stockpile.—In response to tin shortages during World War II, the United States stockpiled refined tin metal from approximately 1946 to 1953. Prior to the 1985 price collapse, tin comprised about 60 percent of the value of all commodities held for strategic purposes. Starting in the 1960's, Congress periodically ordered gradual disposal of additional portions deemed excess to U.S. needs. In October 1988, the U.S. stockpile was about 173,000 metric tons of tin. Approximately 136,000 metric tons are currently (1989) deemed excess and are marked for eventual sale on world markets. The United States planned to sell 7,500 metric tons of tin in fiscal years 1990 and 1991, some 2,500 metric tons more than in 1989 (Tin International, 1989b).

Economic and geographic distribution of tin deposits.—Significant tin resources are found predominantly in Southeast Asia, Brazil, and China. The richest deposits are in Brazil, and together with deposits in Southeast Asia contain 75 percent of the world's demonstrated tin resources. Approximately 73 percent of tin production was consumed in industrial economy countries in 1980, but more than 85 percent was produced in low- and middle-income countries, with roughly 80 percent coming from just four countries: Malaysia, Indonesia, Thailand, and Bolivia. While these percentages had shifted markedly by 1989, with Brazil becoming the world's largest tin producer, the economic and geographic distinction between source and use destination is still valid.

Government-owned and -operated mining and smelting companies.—The past 3 decades have seen a significant increase in the number of state or government owned and operated mining concerns, particularly in low- and middle-income countries. About 44 percent of current Western production capacity is wholly or substantially state owned (Mining Journal, 1987, p. 18). This trend has had a deleterious effect on private investment in the tin-mining industry worldwide, as firms have feared poor treatment by foreign governments. The tin-smelting industry has also undergone significant ownership and location changes in recent years as national governments have asserted greater control over processing of mined tin. Influence of European interests has decreased, while local governmental interests have increased, as occurred, for example, in Indonesia. As a result, smelting-industry concentration has been reduced, and the control of mined ore, rather than the ability to process it, has become the critical factor in the production and processing.

Association of Tin Producing Countries.—In 1983, the Association of Tin Producing countries (ATPC) was formed to foster close cooperation among producing-member countries to maintain stable prices and to safeguard member's interests. The ATPC's role has grown steadily since the dissolution of production quotas and the demise of the ITC after the tin-market collapse in October 1985. Although not ATPC members, Brazil and China have the capability to upset any export control scheme of the ATPC because of their large production capabilities and low operating costs. Brazil, for example, increased its 1988 production to an amount greater than its assigned "quota" (Mining Journal, 1989a). Current ATPC members include Australia, Bolivia, Indonesia, Malaysia, Nigeria, Thailand, and Zaire.

Tin recycling.—In addition to tin mining, recycled or secondary tin represents an important source of tin particularly for the United States. While not useful for tinplate due to impurities, reprocessed tin can be substituted for primary tin in most uses. In times of strategic need, this capacity could be increased relatively quickly and on a relatively cost effective basis with current technology (Baldwin, 1983, p. 55).

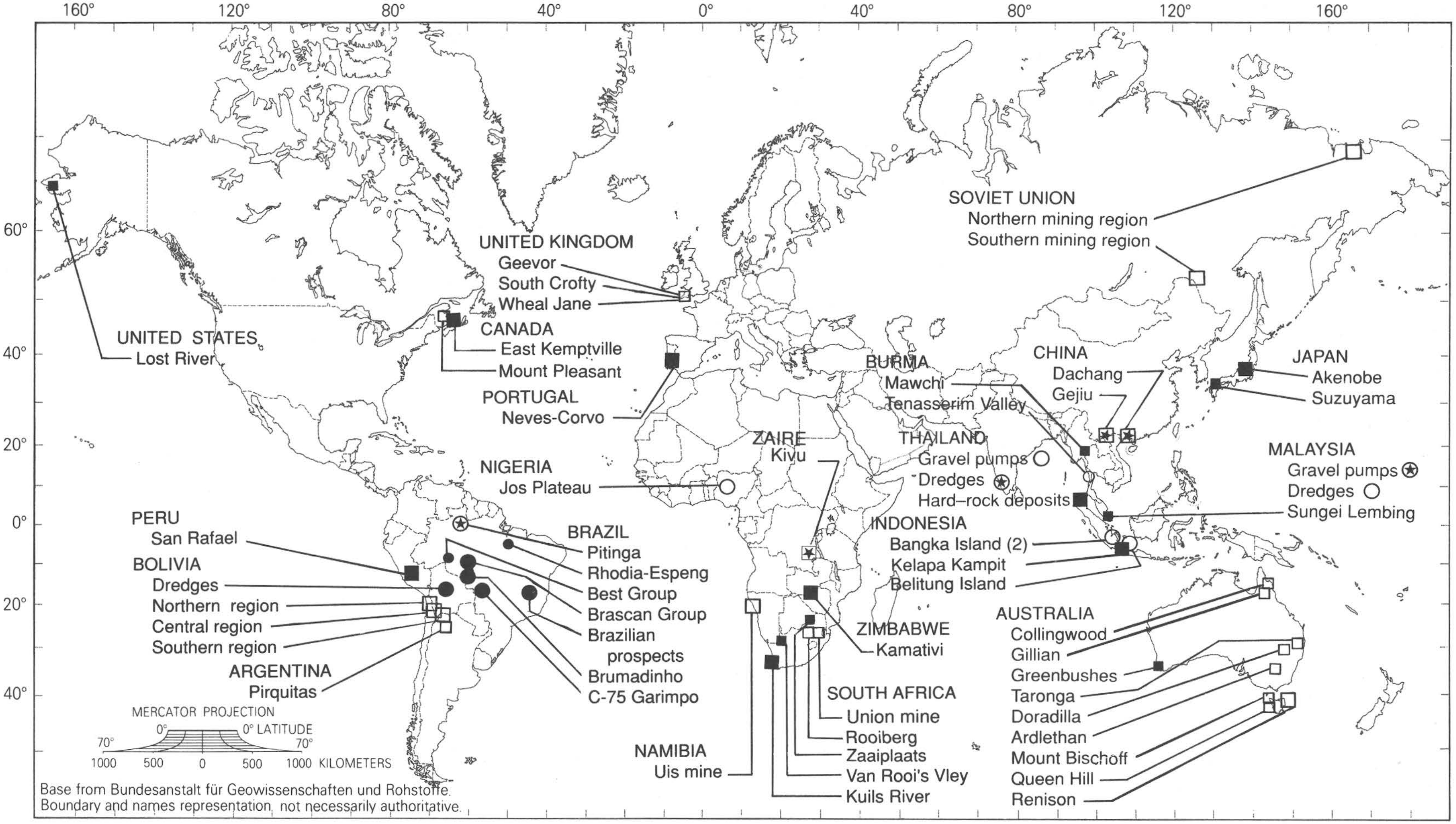
DISTRIBUTION OF TIN DEPOSITS

Cassiterite (SnO_2) contributes almost all the tin of industry, although in Bolivia small amounts are recovered from tin-sulfide minerals such as cylindrite ($Pb_3Sn_4FeSb_2S_{14}$), stannite (Cu_2FeSnS_4), and teallite ($PbSnS_2$). The world map in figure 3 shows the locations of major tin deposits and districts. Some map locations represent only one mine or deposit, while others represent several sites where disaggregated data for individual mines or deposits were proprietary or not available. For example, data for Malaysian gravel pump mines were compiled as one aggregate record rather than as scores of records for individual operations. Also, map locations that represent more than one inventory record within a country or district grouping, such as Banka Island, Indonesia, have the number of records in parentheses. Locations of deposits in Malaysia and Thailand are included in figure 4, which shows the location of tin-bearing areas along the Southeast Asian Tin Belt.

Taylor (1979, p. 7–9) described the following four geologic environments in which tin deposits are present: (1) granitoids associated with layered igneous complexes of the Bushveld type, (2) anorogenic granitoids associated with fracturing-rifting of the stable cratons, (3) Precambrian shields excluding environments 1 and 2 above, and (4) granitoids normally associated with post-Precambrian mobile zones and with periods of major orogeny (postorogenic emplacement within fold belts). The latter environment is the most important economically. The geologic ages of the world's tin provinces are believed to cluster around past major orogenic events (Taylor, 1979, p. 11), with the Jurassic-Cretaceous Kimmeridgian orogeny in Europe being a major tin-producing event.

Major tin deposits and districts in this report are generally of two distinctly different geologic deposit types: lodes and placers. Figure 3 shows 39 locations of lode deposits and 17 locations of placer deposits and the size of the deposits according to the amount of tin contained in the reported identified economic resources (R1E). There are six very large (greater than 500,000 metric tons of contained tin in reported R1E) deposits or groups of deposits. Another 13 large (greater than 100,000 metric tons of contained tin reported in R1E) deposits or groups of deposits, 13 medium-size deposits (greater than 10,000 metric tons and less than 100,000 metric tons of contained tin in reported R1E), 9 small-size deposits (less than 10,000 metric tons of contained tin in reported R1E), and 15 deposits with no reported R1E are included in the inventory. Table 1 lists the geologic deposit types and their subdivisions.

The following summaries include the most common tin deposit types—in terms of production, conditions of formation, petrology, and mineral association.



EXPLANATION

Geologic deposit type

Lode				Placer			
Symbol	R1E (metric tons)	Symbol	R1E (metric tons)	Symbol	R1E (metric tons)	Symbol	R1E (metric tons)
⊠	>500,000			⊛	>500,000		
□	100,000 - 500,000	▪	< 10,000	○	100,000 - 500,000	•	< 10,000
■	10,000 - 100,000	▫	Unreported	●	10,000 - 100,000	◦	Unreported

FIGURE 3. Location, deposit type, and estimated resources of major tin deposits and districts in the world. Numbers in parentheses indicate number of records (deposits and districts) for each location. Location names are from the tables in Part II.

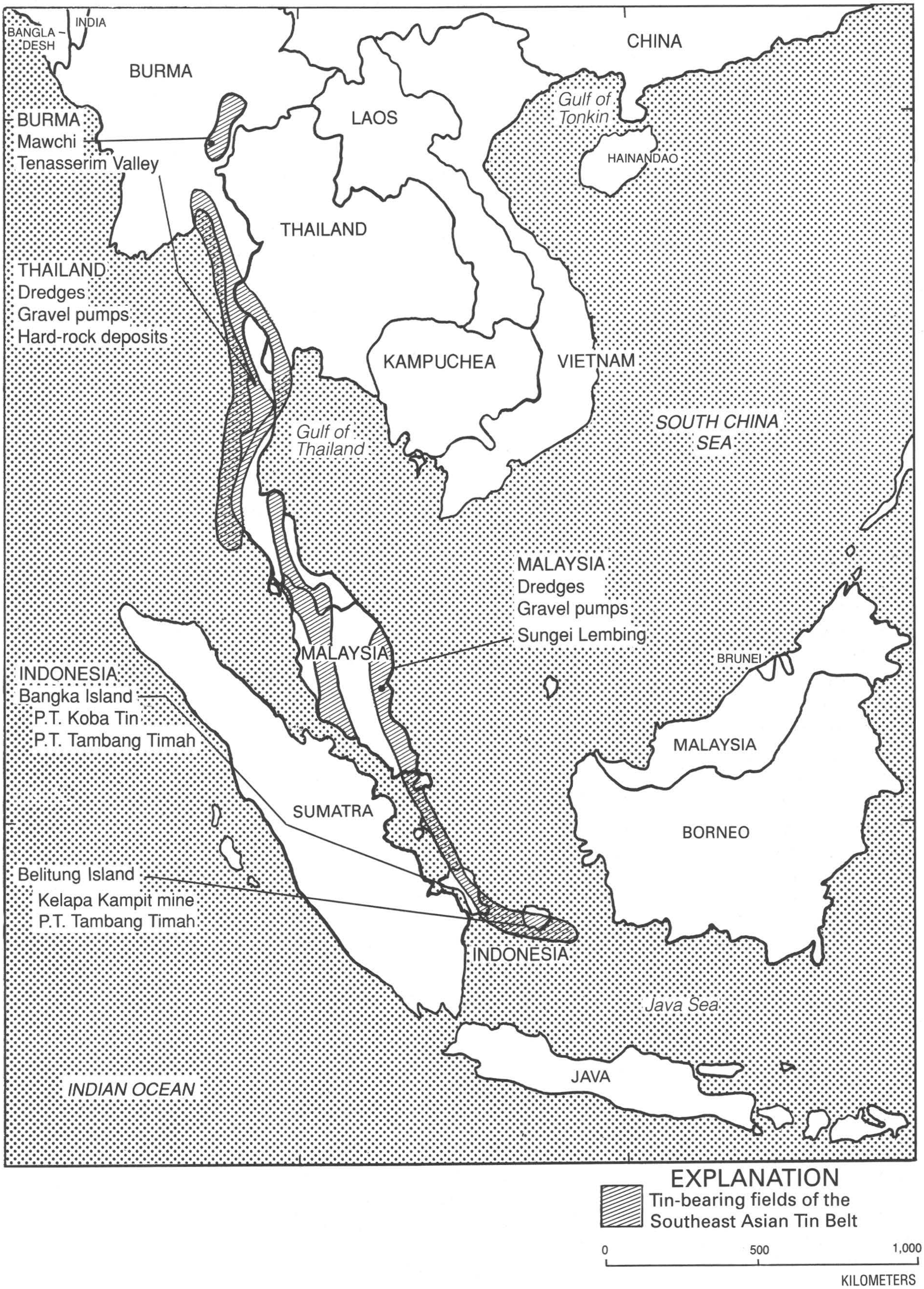

100°
110°
20°
10°
INDIA
BANGLA-DESH
BURMA
CHINA
LAOS
Gulf of Tonkin
HAINANDAO
BURMA
Mawchi
Tenasserim Valley
THAILAND
THAILAND
Dredges
Gravel pumps
Hard-rock deposits
KAMPUCHEA
VIETNAM
SOUTH CHINA SEA
Gulf of Thailand
MALAYSIA
Dredges
Gravel pumps
Sungei Lembing
MALAYSIA
BRUNEI
INDONESIA
Bangka Island
P.T. Koba Tin
P.T. Tambang Timah
MALAYSIA
SUMATRA
BORNEO
Belitung Island
Kelapa Kampit mine
P.T. Tambang Timah
INDONESIA
Java Sea
JAVA
INDIAN OCEAN
EXPLANATION
Tin-bearing fields of the Southeast Asian Tin Belt
0
500
1,000
KILOMETERS

TABLE 1.—*Geologic deposit types represented by deposits in the ISMI tin inventory*

[Number of records is in parentheses]

Geologic deposit	Subclassifications[1]
Lode (39)	Pneumatolytic-hydrothermal (21)
	Replacement, including skarn (8)
	Subvolcanic (4)
	Pegmatite (5)
	Massive sulfide (1)
Placer (17)	Dredge, marine (3)
	Dredge, onshore (4)
	Gravel pump (10)

[1] Lode deposits are subdivided by geologic criteria, while placer deposits are subdivided by mining method. There are no examples of rhyolite-hosted deposits in the ISMI tin inventory.

Lode deposits

Pneumatolytic-hydrothermal deposits.—These deposits include lodes of the Cornwall type, greisen veins, massive greisenized granite, plutonic breccia and porphyry systems, stockworks and sheeted veins, and quartz-cassiterite-sulfide veins (Sainsbury and Reed, 1973; Taylor, 1979; and Hosking, 1974). They represent the major part of the world's lode tin deposits. Lodes generally occur within or near the apical parts (cupolas or cusps) of biotite or biotite-muscovite granite and typically are mineralogically complex fissure fillings or greisen veins in diverse types of country rock. Economically viable massive greisen deposits contain 5 to 50 million metric tons of ore at grades ranging between 0.1 and 0.4 percent tin (Menzie and Reed, 1986a).

Replacement (including skarn) deposits.—Replacement and skarn deposits are characteristically associated with igneous contacts. Prime requirements for development of carbonate replacement tin deposits include the presence of carbonate-rich units, an evolved (specialized) tin granite, and a well-developed brittle fracture system. If carbonate rocks are on the order of 300 m or less from the granite, skarn is more likely to form; at distances greater than 300 m, replacement deposits may develop in the carbonate rocks. Carbonate replacement deposits consist chiefly of cassiterite and sulfide minerals and contain 2 to 50 million metric tons of ore at grades ranging between 0.5 and 1 percent tin (Menzie and Reed, 1986b). Tin minerals in skarn deposits are erratically distributed, and much of the tin is present in silicate minerals that are not amenable to normal recovery methods. In the Lost River area, Alaska, tin is a potential byproduct of beryllium and fluorite production from replacement veins and skarn deposits (Sainsbury, 1964, 1969). At Renison, Tasmania, one of the world's largest underground tin mines, the main deposits are quartz-cassiterite-sulfide replacement lodes in carbonate strata (Patterson and others, 1981).

◀ FIGURE 4. Tin-bearing areas in Southeast Asia (after Bleiwas and others, 1986, p. 18). Location names are from the tables in Part II.

Subvolcanic deposits.—Traditionally, this category (also called "telescoped" or xenothermal deposits (Hosking, 1974)) is typified by the rich tin-silver veins of southern Bolivia. The deposits occur in very high level stocks beneath or within vents of volcanoes. The veins contain, in addition to cassiterite, abundant sulfosalt and sulfide minerals containing silver, arsenic, bismuth, lead, and zinc. The presence of these rare tin minerals makes recovery of tin difficult. Individual Bolivian mines have produced more than 500,000 metric tons of tin; the associated classic "porphyry" tin deposits (Sillitoe and others, 1975), although exceedingly large (in excess of 100 million metric tons), contain only 0.1 to 0.3 percent tin and are not now economic producers. It should be noted that some tin lodes in high-level stocks, pipes, or breccia systems that did not vent are also referred to as "porphyry" tin deposits.

Pegmatite deposits.—Most tin-bearing pegmatites occur in Precambrian shield terrains (the smaller Mesozoic pegmatites in Thailand are an exception), where cassiterite is recovered along with co-product columbite, tantalite, beryl, spodumene, and wolframite. The most productive pegmatites occur in areas of deep tropical weathering (central and southern Africa, Western Australia), which contributes to lower mining costs. Worldwide, tin production from pegmatites is minor.

Rhyolite-hosted deposits (Mexican type).—Deposits of this type consist of discontinuous fracture fillings of cassiterite and wood tin (a colloform variety of cassiterite), along with specular hematite and chalcedony, near the margins of Tertiary alkali-feldspar rhyolite flow domes and as disseminated cassiterite in volcanic breccia (Reed and others, 1986). No deposits of this type are included in the ISMI tin inventory. Grades are generally erratic and quite low. Most deposits contain between 230 and 3,900 metric tons of ore at grades between 0.14 and 1.04 percent tin (Singer and Mosier, 1986). Production of tin from these deposits is generally limited to small placer operations that may have produced a few tens of metric tons of tin each. Many rhyolite-hosted tin deposits lie in the mid-Tertiary volcanic province of the Sierra Madre Occidental located in central and northern Mexico. A few deposits are present in the Western United States, such as those in New Mexico's Black Range.

Massive sulfide deposits.—Fine-grained cassiterite may be present in massive base metal sulfide deposits mined for copper, zinc, and lead. Deposits of this type can be assigned to two major groups: exhalative volcanogenic, hosted primarily in volcanic rocks, and exhalative sedimentary, hosted in sedimentary rocks (Hutchinson, 1981). These deposits form by chemical precipitation of metalliferous hydrothermal brines discharged from fumarolic vents on sea floors. Because the average tin content of massive sulfide deposits is generally less than 0.1 percent, they are, worldwide, minor tin producers. In some deposits, however, tin is present in amounts sufficient to be recovered as a byproduct. For many years the famous zinc-lead-silver exhalative sedimentary massive sulfide body at Sullivan, British Columbia, produced tin as a byproduct. Recently, the Neves-Corvo volcanogenic massive sulfide copper deposit in the Iberian pyrite belt of Portugal is reported to contain a 2.8-million-metric-ton ore body that has the exceptionally high grade of 2.6 percent tin (Mining Journal, 1988b; Carvalho, 1988). Tin will be produced as a byproduct of copper mining. If the planned production of 5,000 metric tons of tin per year is achieved, it will make Neves-Corvo the largest tin producer in Europe.

Placer deposits

Because cassiterite is both heavy and chemically stable in the surficial environment, it is commonly concentrated in placers—deposits that form over or near bedrock source areas where weathering and erosional processes remove lighter rock materials and gravity assists in concentrating heavy minerals. Tin placers locally contain recoverable amounts of other heavy minerals, such as columbite-tantalite, wolframite, ilmenite, monazite, zircon, and xenotime. Alluvial placers are the largest and richest placers. They occupy both modern and ancient stream beds, and in Southeast Asia many alluvial placers now lie beneath seawater and are mined by seagoing dredges. Exceedingly low-grade placer deposits having a grade of less than 0.01 percent tin can be mined economically by dredging. Placers are classed as residual, eluvial (slope), or alluvial (stream) or as marine and fossil placers (Sainsbury and Reed, 1973).

Residual placers form in place by the chemical decay and removal of the rock minerals from a bedrock cassiterite source. Residual placers may grade downward into weathered lodes where they are mined either as placers or as open-pit lodes.

Eluvial placers are formed by the chemical decay of tin-bearing rocks and the gravity separation of cassiterite and other heavy minerals as the decayed mantle moves downslope under the influence of sheetwash, gravity, and frost action. Such placers grade imperceptibly into residual placers upslope and into alluvial (stream) placers downslope.

Alluvial placers furnish most of the world's tin. For many years, more than half the world's tin production came from alluvial placers in Southeast Asia. More recently, exceptionally rich alluvial placers are being developed in Brazil. Alluvial placers occupy both modern and fossil stream beds, and the distribution of cassiterite is dependent upon the location of the source areas and the hydraulics of running water. The highest grade placers are formed near lodes along sections of stream where the velocity is high enough to result in good gravity separation but not so high that the channel is swept clean.

Marine placers form where a marine shoreline intersects or transgresses either a stream valley containing alluvial cassiterite or a bedrock source of tin. Beach placers commonly have a large length-to-width ratio, but a placer of transgressive origin may consist of a sheet of heavy minerals buried beneath marine sediments. The largest marine placers occur off Bangka and Billiton (Belitung) Islands (Indonesia) and along the coasts of Thailand and Burma.

Any of the above types of placers may become fossil placers as a result of burial beneath subsequently deposited sediments or lava. Uplift and renewed erosion along disrupted drainages may expose fossil placers, and second-cycle alluvial placers may form, as has occurred in Nigeria.

Information for placer deposits in the ISMI tin inventory is grouped by the three methods used in their mining: onshore and marine dredges and gravel pumps (table 1). Deposits at Jos Plateau in Nigeria are mined by use of gravel pumps and open-pit methods.

Onshore and marine dredges.—Dredges are self-contained, floating, excavating machines and concentrators that have been used to recover placer tin and other mineral commodities since the turn of the century. The most common type of dredge is the bucket-line dredge (fig. 5) consisting of a series of buckets on a chain connected to a ladder-type structure that positions the buckets and controls excavation. Dredges are capital intensive, requiring a multimillion dollar investment before mining can commence. The mining capacity of the dredge depends on the size and speed of the buckets. Dredges remove overburden and ore and may operate either onshore or offshore. In 1980, offshore dredges accounted for 12.3 percent of world tin production and onshore dredges 7.3 percent (Robertson, 1982, p. 18).

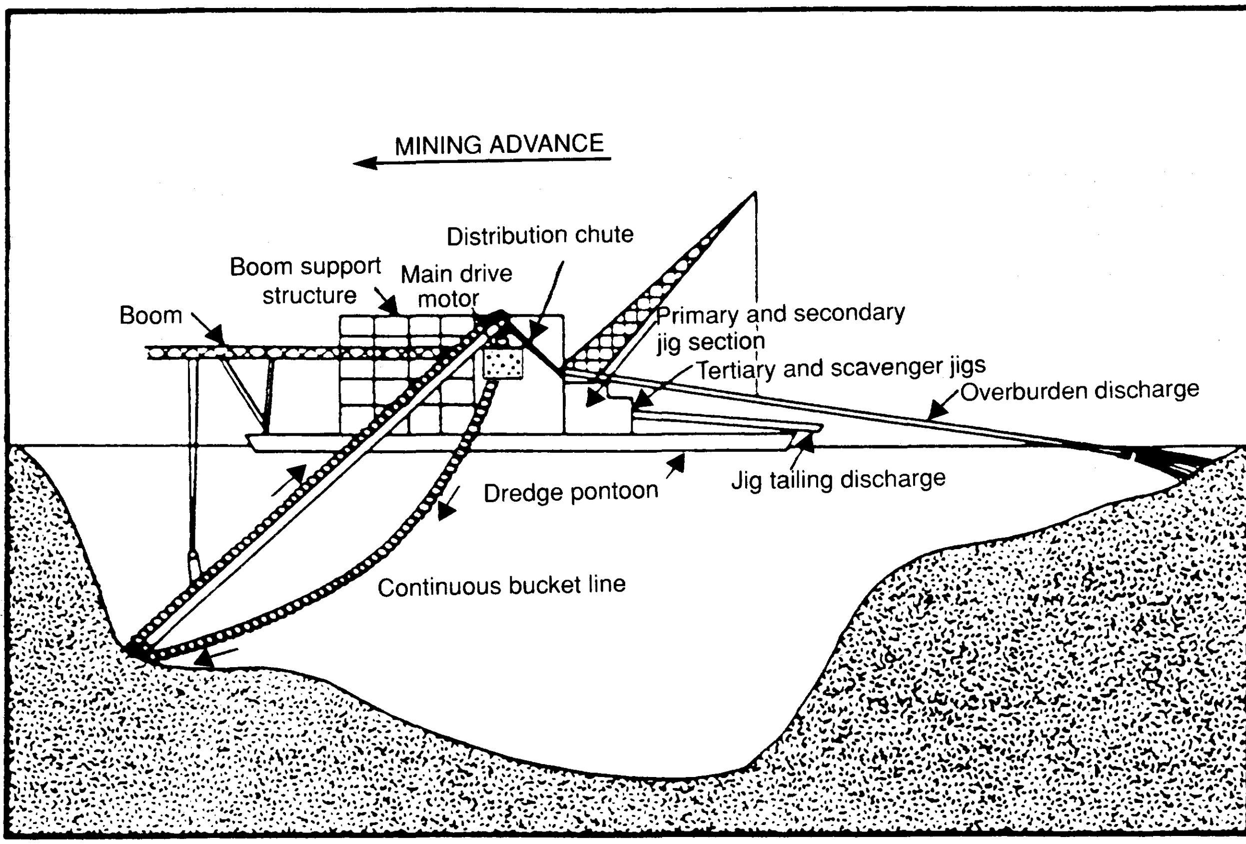


FIGURE 5. Typical bucket-line dredge and outboard concentrating plant (from Bleiwas and others, 1986).

For onshore dredges, removal of material ahead of the dredge produces a pond on which the dredge can advance. The larger dredges can excavate to a maximum depth of about 45 m. In the 1950's, Malaysian onshore dredges accounted for over one-half of production; that figure dropped to one-third in the 1960's. At the end of 1981, there were 60 onshore dredges operating in Malaysia; by mid-1986, however, the number had dropped to 31 (American Metal Market, 1987, p. 177).

Offshore (marine) dredges are designed to allow for the effect of wave action on the bucket ladder and have been operating since the first dredge was introduced offshore from Thailand in 1907 (Robertson, 1982, p. 17). Weather conditions, currents, and wave action in the open sea may reduce the efficiency of marine dredges and raise operating costs. The largest offshore dredges have a bucket capacity of about 30 ft^3 (0.85 m^3) and operate at depths up to about 60 m in relatively calm waters close to shore.

Bleiwas and others (1986, p. 33) showed dredging to be the lowest cost method of mining and beneficiating tin ore with an average of $0.70 per metric ton of dredged ore, although costs vary among operations because of the characteristics of the ore body and overburden. Malaysian dredges were the most cost efficient, with an average operating cost of $0.50 per metric ton of ore. At Brazil's rich Pitinga deposit, where 19 onshore dredges are currently operating, mining costs were less than $3 per cubic meter, or about $1.90 per metric ton (Thorman and Drew, 1988). Offshore dredges are slightly more costly to operate than onshore dredges and are susceptible to delays due to weather conditions at the dredgesite. Because of the large initial investment needed to start a dredging operation, use of the dredges in low- and middle-income countries is justified only for large deposits.

Gravel pumps.—Gravel-pump mining is a low-capital method for concentrating cassiterite from placer deposits not amenable to dredging. In Malaysia, for example, gravel pump mines typically rework tailings or pockets of gravel in previously mined areas. Gravel pumps are versatile and handle combinations of mud, sand, and coarse gravel and quickly adjust to variations in slurry concentration. Advantages of gravel-pump mining over dredging include (1) topography is relatively unimportant to gravel pumps, and they are espe-

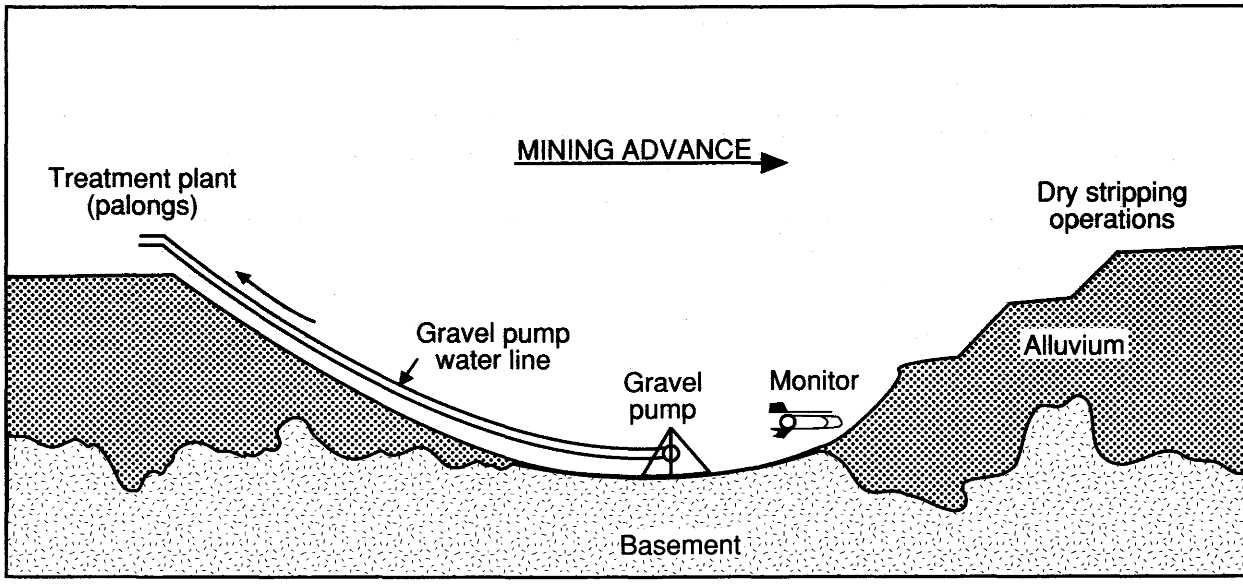


FIGURE 6. Typical gravel-pump operation (from Bleiwas and others, 1986).

cially effective for working in areas of large boulders or irregular topography (for example, limestone pinnacles in Malaysia); (2) a deposit can be selectively mined; (3) complete extraction of the cassiterite-bearing gravels is generally possible; and (4) the same equipment can mine at various depths.

Gravel pumps consist of three basic components (fig. 6), a monitor or high-pressure nozzle, a pumping station, and a concentrating section. The monitor directs high-pressure water to erode exposed tin-bearing surfaces. The resulting slurry is channeled to the pumping station where most undesirable materials, such as clay, boulders, and wood, are removed. The remaining material is pumped to the concentrating section, which removes the cassiterite and other heavy minerals, such as apatite, monazite, rutile, and zircon, from the waste. As of 1980, gravel pumps provided 28.5 percent of the world's tin (Robertson, 1982, p. 18). At the end of 1978, there were 833 gravel pumps in operation in Malaysia; that number had declined to 116 by mid-1986 (American Metal Market, 1987, p. 177). Gravel pumps had an average mining and beneficiation cost of about $1.10 per metric ton of ore—ranging from $0.90 per metric ton for low-grade Malaysian ore to $4.70 for high-grade ore in Australia, Bolivia, Burma, and Zaire (Bleiwas and others, 1986). Although costs vary widely, in the Southeast Asian Tin Belt about 50 percent of the cost of gravel pump mining goes for power and labor (Robertson, 1982, p. 28).

Open pits and other methods.—Some alluvial deposits and deeply weathered lodes (referred to as "softies") are worked with mechanized shovels, drag lines, excavators, or by manual labor. Subsequent processing of the ore is generally by gravel pump methods. Open-cast mines in Australia, Nigeria, and Zaire are large, and the residual placers of Jos Plateau, Nigeria, are worked as large open pits. Large hard-rock open-pit tin mines, common in other sectors of the mining industry, are relatively rare. The low-grade massive greisen deposit at East Kemptville, Nova Scotia, the only primary tin-producing mine in North America, is a hard-rock open-pit operation having a planned annual production of 4,700 metric tons of tin-in-concentrate (Moyle, 1984).

Tin is also recovered by dulang washing, which is simply panning mine tailings for cassiterite not recovered by previous mining. While individual dulang washing operations are very small, collectively they account for about 5 percent of Malaysian output and 2 to 3 percent of Thailand's output (Robertson, 1982, p. 20).

Figure 7 shows the global distribution of major tin deposits and districts and indicates economic class (GNP per capita) of countries where major tin deposits are located.

TIN RESOURCES

A summary of the R1E resources of countries having major tin deposits and districts in the ISMI tin

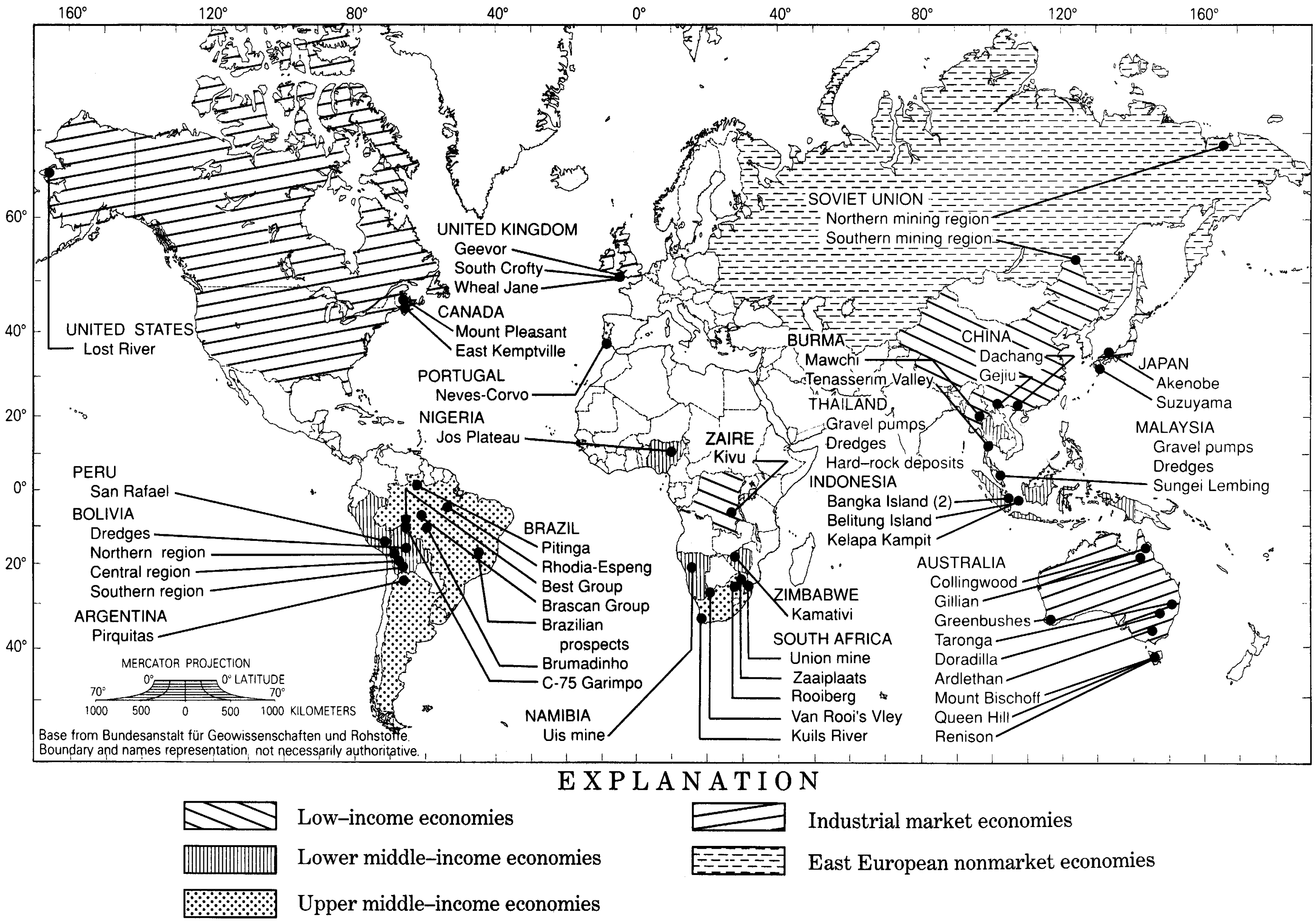


FIGURE 7. Economic classification of the World Bank (1986, p. 180–181), based principally on gross national product per capita, for countries where the world's major tin deposits and districts occur. Numbers in parentheses indicate the number of records (deposits and districts) for each location. Location names are from the tables in Part II.

TABLE 2.—*Known economic tin resources in the world's major deposits and districts, by country, deposit type, and mining method*

[Includes only countries having major tin deposits in the International Strategic Minerals Inventory. See figure 3. Figures are based on data reported in table 10 of Part II and are in thousand metric tons. Figures may not add to totals shown due to rounding. N.r.=None reported]

Rank	Country	Economic class[1]	Number of records	Resources		Deposit type			Mining method		
						Placer		Lode			
				R1E[2]	Percent	Gravel pump	Dredge		Surface	Underground	Surface and underground
1.......	China	L	2	1,562.5	20.25	N.r.	N.r.	1,562.5	N.r.	1,562.5	N.r.
2.......	Malaysia	UM	3	1,207.6	15.65	900.0	300.0	7.6	1,200.0	7.6	N.r.
3.......	Brazil	UM	7	[3]1,195.5	15.49	134.6	1,060.9	N.r.	1,195.5	N.r.	N.r.
4.......	Thailand	LM	3	938.4	12.16	244.6	620.1	73.7	864.7	73.7	N.r.
5.......	Indonesia	LM	4	821.3	10.64	271.8	526.3	23.2	798.1	23.2	N.r.
6.......	Zaire	L	1	510.0	6.61	N.r.	N.r.	510.0	510.0	N.r.	N.r.
7.......	Bolivia	LM	4	453.7	5.88	N.r.	12.8	440.9	12.8	440.9	N.r.
8.......	Soviet Union	E	2	300.0	3.89	N.r.	N.r.	300.0	150.0	150.0	N.r.
9.......	Australia	I	9	207.8	2.69	N.r.	N.r.	207.8	3.6	204.2	N.r.
10.......	Namibia	LM	1	120.8	1.57	N.r.	N.r.	120.8	120.8	N.r.	N.r.
11.......	Nigeria	LM	1	110.8	1.44	110.8	N.r.	N.r.	110.8	N.r.	N.r.
12.......	Canada	I	2	92.4	1.20	N.r.	N.r.	92.4	92.4	N.r.	N.r.
13.......	Portugal	UM	1	72.8	.94	N.r.	N.r.	72.8	N.r.	72.8	N.r.
14.......	Japan	I	2	41.7	.54	N.r.	N.r.	41.7	N.r.	41.7	N.r.
15.......	Zimbabwe	LM	1	31.7	.41	N.r.	N.r.	31.7	N.r.	N.r.	31.7
16.......	South Africa	UM	5	24.2	.31	N.r.	N.r.	24.2	N.r.	N.r.	24.2
17.......	Peru	LM	1	22.5	.29	N.r.	N.r.	22.5	N.r.	22.5	N.r.
18.......	United States	I	1	2.4	.03	N.r.	N.r.	2.4	N.r.	2.4	N.r.
19.......	Burma	L	2	.4	.01	N.r.	N.r.	.4	N.r.	.4	N.r.
20.......	Argentina	UM	1	N.r.		N.r.	N.r.	N.r.	N.r.	N.r.	N.r.
21.......	United Kingdom	I	3	N.r.		N.r.	N.r.	N.r.	N.r.	N.r.	N.r.
	Total		56	7,716.6	100.00	1,661.8	2,520.1	3,534.7	5,058.7	2,602.0	55.9

[1] Based primarily on GNP per capita and, in some cases, other distinguishing economic characteristics (World Bank, 1986, p. 180–181). Countries where major tin deposits or districts occur are, by class: L=low-income economies—Burma, China, and Zaire; LM=lower middle-income economies—Bolivia, Indonesia, Namibia, Nigeria, Peru, Thailand, and Zimbabwe; UM=upper middle-income economies—Argentina, Brazil, Malaysia, Portugal, and South Africa; I=industrial market economies—Australia, Canada, Japan, the United Kingdom, and the United States; E=eastern European nonmarket economies—the Soviet Union. A sixth economic class, high-income oil exporters, is not listed because those countries do not have identified major tin deposits.

[2] Reliable estimates from identified deposits having economically exploitable resources (fig. 1).

[3] A recent report (Kashida and others, 1990, p. 900) estimates Barzil's tin "reserves" to be 4 million metric tons.

inventory is presented in table 2, where the resources are shown according to deposit type and mining method. China has the largest tin R1E resources, all of which are in lode deposits and mined from underground. In the next four countries having the largest resources (Malaysia, Brazil, Thailand, and Indonesia), tin is chiefly in placer deposits that are mined by gravel pumps or dredges. Of the more than 7.5 million metric tons of reported tin R1E resources, about 65 percent is mined from the surface and 35 percent from underground.

Table 3 shows the resources of major tin deposits and districts according to geologic deposit type. Although placer deposits account for 54.0 percent of reported known economic resources (R1E), lode deposits make up about 87 percent of the reported resources in other categories.

Tin deposits or districts represented by the six very large size (greater than 500,000 metric tons) symbols in figure 3 account for almost 60 percent of the R1E resources and over 5 percent of the reported resources other than R1E. The 13 deposits or districts represented by the 12 large-size (100,000 to 500,000 metric tons) symbols in figure 3 account for over 32 percent of the R1E resources and over 39 percent of the reported resources other than R1E. Deposits represented by the 13 medium-size (10,000 to 100,000 metric tons) symbols account for over 7 percent of R1E and 21 percent of

TABLE 3.—*Tin resources in the world's major deposits and districts, by geologic deposit type and resource category*

[Figures are in metric tons of contained tin; figures in parentheses are percent of column totals. Figures may not add to totals shown due to rounding]

Geologic deposit type[1]	Number of records	Resource category			
		R1E[2]		All other R1 and R2[3]	
Lode...........	39	3,535,000	(45.8)	1,284,000	(87.1)
Placer..........	17	4,182,000	(54.2)	189,800	(12.9)
Total.....	56	7,717,000	(100)	1,473,000	(100)

[1] Deposit types of the world's major tin deposits are shown in figure 3. Subclassifications of deposit types are listed in table 1.

[2] Reliable estimates from identified deposits having economically exploitable resources (fig. 1).

[3] That is, resources in the R1M, R1S, R2E, and R2S (fig. 1).

TABLE 4.—*Tin resources in the world's major deposits and districts, by economic class of country and resource category*

[Figures are in metric tons of contained tin; figures in parentheses are percent of column totals. Figures may not add to totals shown due to rounding. N.r.=none reported]

Economic class[1]	Number of records	Resource category[2]			
		R1E		All other R1 and R2	
Low-income	5	2,073,000	(26.9)	70,000	(4.8)
Lower middle-income	15	2,499,000	(32.4)	590,300	(40.0)
Upper middle-income	17	2,500,000	(32.4)	238,300	(16.2)
Industrial market	17	344,300	(4.5)	574,900	(39.0)
Eastern European nonmarket	2	300,000	(3.9)	N.r.	
Total	56	7,717,000	(100)	1,473,000	(100)

[1] Based principally on GNP per capita and, in some instances, other distinguishing economic characteristics (World Bank, 1986, p. 180–181). Countries where major tin deposits or districts occur are, by class: low-income economies-- Burma, China, Zaire; lower middle-income economies—Bolivia, Indonesia, Namibia, Nigeria, Peru, Thailand, Zimbabwe; upper middle-income economies—Argentina, Brazil, Malaysia, Portugal, South Africa; industrial market economies—Australia, Canada, Japan, the United Kingdom, the United States; and eastern European nonmarket economies—the Soviet Union. A sixth economic class, high-income oil exporters, is not listed because those countries do not have identified major tin deposits.

[2] Categories are defined in figure 1.

other resources, and deposits represented by the 9 small-size (less than 10,000 metric tons) symbols account for less than 1 percent of R1E resources and 4 percent of resources in other categories. The 15 deposits having no reported R1E resources include 12 deposits that report more than 29 percent of resources other than R1E.

Table 4 shows the distribution of resources (metric tons of contained tin) of major tin deposits among the World Bank country economic classes from figure 7. Low-income economy countries have five deposits and 26.9 percent of R1E resources. Of these five deposits, three (Dachang, Gejiu, and Kivu) are in the very large size category. Countries in this class have only 4.8 percent of resources in other categories. Upper and lower middle-income economy countries rank first and second, respectively, in tin R1E resources. These two middle-income classes contain 32 of the deposits or districts (3 of which are very large size) in the inventory and account for 64.8 percent of R1E resources and 56.2 percent of the other resources. Most of these resources are in placer deposits in the Southeast Asian Tin Belt (fig. 4) and in Brazil. Industrial market economy countries contain 17 deposits or districts but have less than 5 percent of the R1E resources and about 39 percent of the resources in other categories. Australia's Renison mine, a large-size deposit, and Canada's East Kemptville mine and the Akenobe mine in Japan, both medium-size deposits, contain the majority of the R1E tin resources in the industrial market economy class. Deposits in Australia and the United Kingdom are the source of most of the resources other than R1E. The eastern European nonmarket economy countries (consisting of only two tin-bearing regions in the Soviet Union) have about 4 percent of reported R1E resources and no reported resources in other categories. The 300,000-metric-ton figure (Carlin, 1989) for the Soviet Union is suspect, as this country produced an estimated 112,500 metric tons of tin between 1982 and 1986, and annual production for 1987–88 is about 24,500 metric tons per year.

Many countries that consume tin do not have major tin deposits or districts. For this reason, there is significant international trade in tin. On the basis of information from the British Geological Survey (1985), it is estimated that about 80 percent of the tin produced in 1983 was traded that year as concentrate, unwrought tin and alloy, or scrap. When tin re-exports from countries not having mine production in 1983 are included, the amount of tin traded internationally exceeded mine production in that year by 25 percent.

The addition to world tin resources in major deposits by discovery of new deposits is shown in figure 8. Dates of discovery are not always reliable, but about one-third of current tin R1E resources are in deposits such as Dachang and Gejiu in China, which were discovered about 2,000 years ago, and some of the deposits in the Southeast Asian Tin Belt, which were discovered prior to 1860.

Deposits discovered in the 1900–19 period (fig. 8) have another third of R1E resources and include the very large size Malaysian, Thai, and Indonesian dredges and the large Malaysian gravel pump mines; Uis tin in Namibia; and deposits of Jos Plateau, Nigeria. Medium-size deposits, such as the Akenobe mine in Japan, also were discovered during this period.

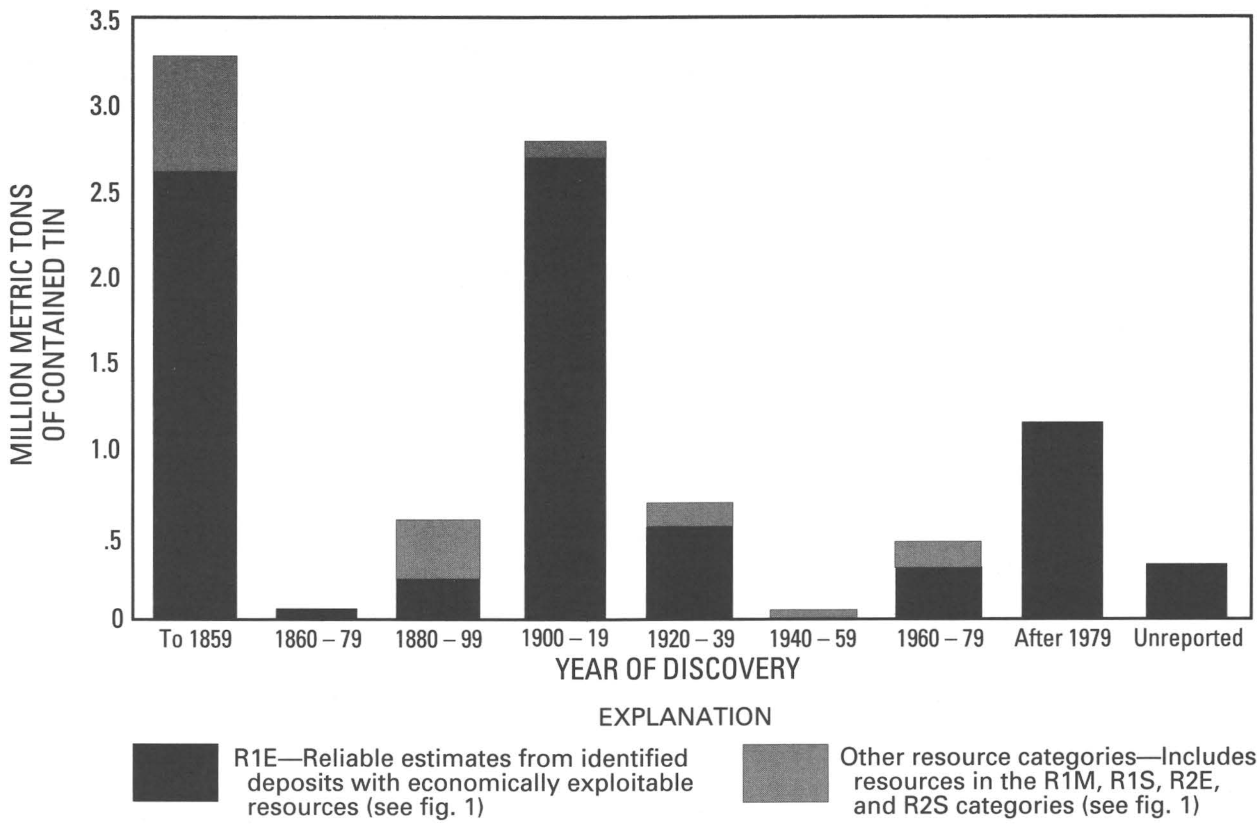


FIGURE 8. Tin resources in the world's major deposits and districts according to their date of discovery. If the year of discovery was not reported, year of first production was used instead. Years of discovery are listed in table 10 of Part II.

The discovery of the large-size Pitinga deposit and the medium-size C–75 Garimpo deposit, both in Brazil, makes the deposits discovered after 1979 the third largest amount of R1E resources with almost 15 percent. In 1986, the reserves at Pitinga were estimated at "575,000 tonnes of high-grade ore sufficient for 30 years production at a rate of 20,000 tonnes of tin per year" (Tin International, 1986, p. 270). (Note, table 10 indicates 500,000 tonnes of R1E, about 17 percent below the Tin International information.) In this report, we estimate the R1E resources at Pitinga at 1 million metric tons (L. J. Drew, oral commun., 1988). More recently, reports of a new tin deposit, possibly even larger than the Pitinga deposit (Mining Journal, 1988a; Tin International, 1989a) suggests that Brazilian tin resources will continue to have considerable impact on the world's tin market for the next several years.

Conclusions drawn from figure 8 should take into account (1) the uncertainty of discovery dates due to difficulties in defining "discovery," (2) the limited validity of assuming all of the deposit's (or district's) resources to the initial discovery date, as is done in this figure, and (3) the different standards used to report resource data from different deposits. Also, there is uncertainty concerning the amount of resources contained in discoveries made since about 1960 as a result of incomplete information about recently discovered deposits and of the time lag in reporting information about new discoveries.

TIN PRODUCTION

The 56 tin deposits and districts in the International Strategic Minerals Inventory occur in 21 countries (fig. 9); these countries have collectively accounted for most of the world's tin production since the mid-19th century. The data plotted in figure 9 include a small indeterminable amount of tin from mines not in the inventory.

Figure 10 shows the production of tin from each of the countries indicated in figure 9. From 1970 to 1987, countries such as Malaysia, Bolivia, and Zaire, which were major tin producers between 1940 and 1960, generally reduced their output; while countries having less significant output between 1940 and 1960, such as

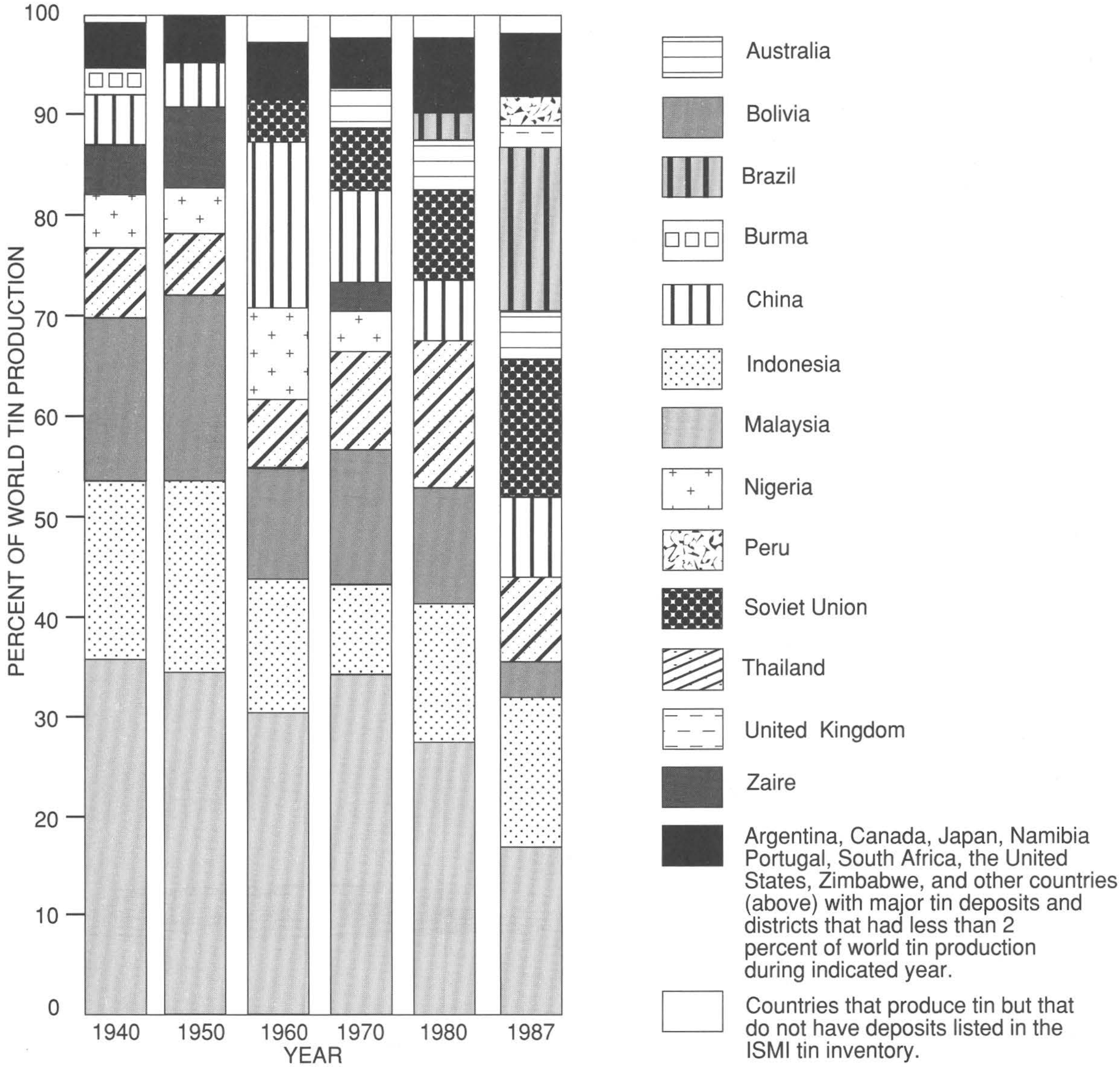


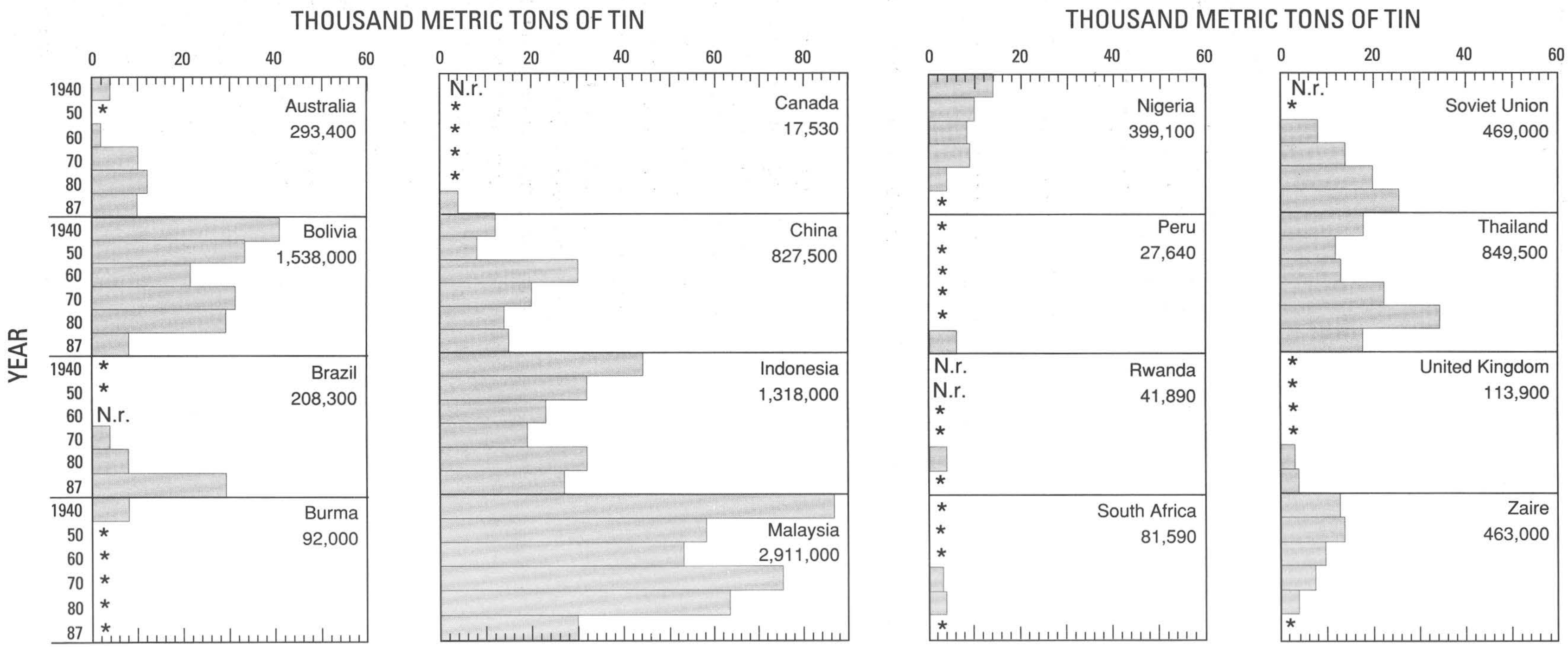
FIGURE 9. Proportions of total world mine production of tin accounted for by countries having major deposits and districts in the ISMI tin inventory, selected years 1940–87. Reported production (U.S. Bureau of Mines, 1943–87) for countries is listed in table 5.

the Soviet Union, Australia, Brazil, and South Africa, increased production.

To better illustrate these trends, tin production from 1980 to 1987 for several of the major producers is shown in figure 11. In this figure, the reduction in production from Malaysia and Bolivia and the ascent of Brazil to the role of second-leading producer in 1987 are evident.

Information on 1987 production and cumulative production from 1934 to 1987 for countries having tin production is shown in table 5. The production data have been grouped by World Bank economic class in table 6.

About 66 percent of 1987 production and three-quarters of cumulative production since 1934 took place in middle-income countries (principally Malaysia, Indonesia, Bolivia, Brazil, and Thailand). Industrial market and eastern European nonmarket economy countries accounted for only 9.4 percent and 14.1 percent of production, respectively, in 1987. For the period 1934 to 1987, tin-producing countries in these economic classes accounted for about 10 percent of the total cumulative production. Low-income countries produced about 10.5



* Reported mine production of less than 2,000 metric tons.
N.r. – None reported

FIGURE 10. Countries having greater than 2,000 metric tons of tin mine production in any one of the selected years 1940–87. Reported mine production is from U.S. Bureau of Mines, (1943–88). Of those countries shown, only Rwanda does not have a deposit in the ISMI tin inventory. Countries that have deposits in the inventory but less than 2,000 metric tons of mine production during the selected years (such as Argentina, Japan, Namibia, Portugal, the United States, and Zimbabwe) are not included. Numbers for each country include the total production from 1940 to 1986 in metric tons.

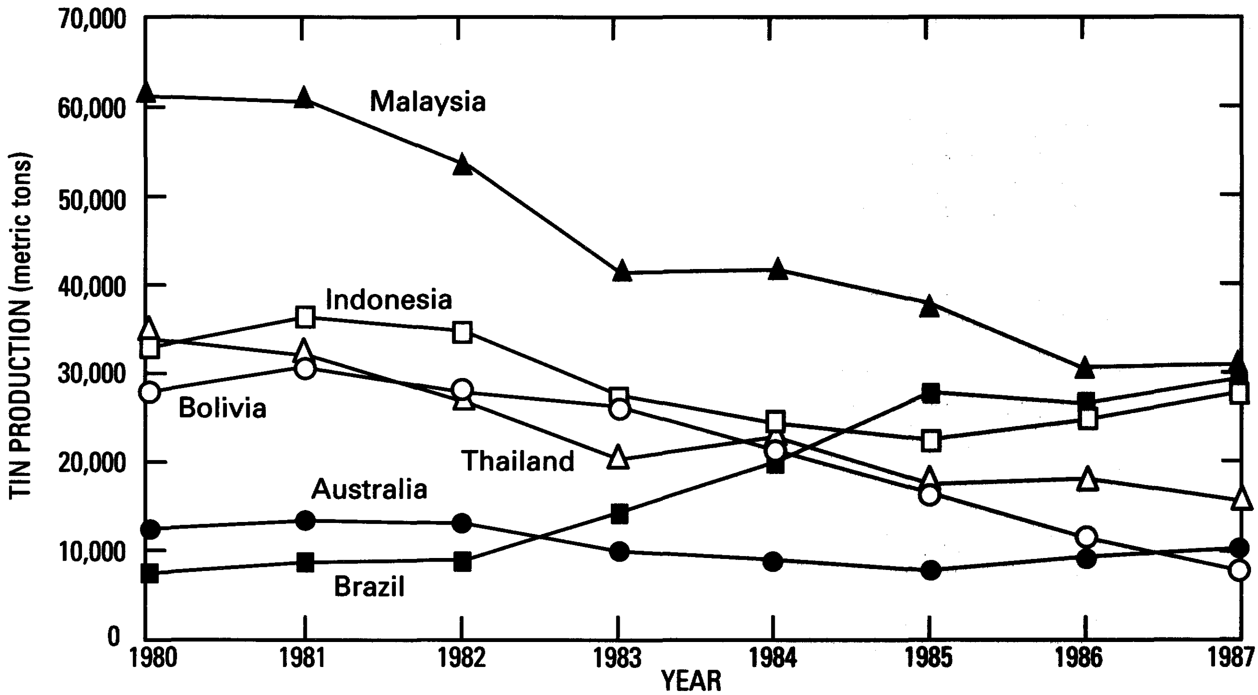


FIGURE 11. Tin production for selected countries from 1980 to 1987. (Source: U.S. Bureau of Mines, 1986–88.)

percent of 1987 production and 14.8 percent of 1934 to 1987 cumulative production.

Table 7 shows the distribution of reported tin R1E resources by mining method and economic class of country, which is listed by individual country in table 2. About two-thirds of the tin R1E resources are in mines, mostly placers, which will be surface mined, and 85 percent of these resources to be surface mined are in middle-income economy countries. About 75 percent of lode-tin resources in the inventory are in deposits that are being are mined by using underground methods or in mines that employ a combination of both underground and surface mining methods. The remaining 25 percent of lode-tin resources in the inventory are in deposits that are mined from the surface. Kamativi, Zimbabwe, is one lode deposit that is mined both from the surface and from underground. Renison, Australia, is presently (1989) being mined from underground after previously being mined by surface techniques. Several other lode deposits, including Greenbushes, Mount Bischoff, and Taronga, Australia; East Kemptville, Canada; Uis tin mine, Namibia; and deposits in the southern tin mining area of the Soviet Union, are (or may be) mined by using strictly surface-mining methods. All placer deposits in the inventory are mined by using surface methods.

One way to measure the structure of the countries that supply a commodity is by the concentration ratio; for example, the percentage of total production contributed by the largest producing countries. Figure 12 shows the four-country and eight-country concentration ratios (or percentage) for 1913 and 1980 production of several nonfuel mineral commodities. By these measures, tin does not rank among those commodities, such as platinum-group-metals, manganese, and chromium, that are strongly dominated (greater than 90 percent) by four countries in either 1913 or 1980. The four-country and eight-country concentrations ratios for 1980 are below those for 1913, although for both years the top eight countries had over 90 percent of world tin production.

Analysis of annual concentration ratios and prices (fig. 13), however, illustrates the difficulty the largest tin-producing countries had in maintaining their share of world tin market. In 1945, at the close of World War II, the four-country concentration ratio was at its peak of almost 85 percent, and the price of tin was about $1,100 per metric ton. The four largest tin-producing nations that year were Bolivia, Zaire, Nigeria, and Malaysia. The two African countries were among the four largest producers because perennial top producers, Thailand and Indonesia, had curtailed output during the war. The eight-country ratio (comprised of production from Malaysia, Bolivia, Indonesia, Zaire, Nigeria, China, Thailand, and Australia) did not reach its peak of 96 percent until 1948 when Indonesia had returned to full

TABLE 5.—*Estimated cumulative and annual mine production of tin, contained in ore and concentrate, for each country having reported production for the period 1934–87*

[Source: U.S. Bureau of Mines, 1940–88, and Richard Levine, 1987, oral commun. Figures are in metric tons of contained tin; numbers in parentheses denote ranking of country. Figures may not add to totals shown due to rounding. *=countries not having deposits in the ISMI tin inventory. N.r.=none reported]

Country[1]	Cumulative production 1934–87		Annual production 1987 (estimate)	
Malaysia	2,911,000	(1)	30,388	(1)
Bolivia	1,538,000	(2)	7,000	(8)
Indonesia	1,318,000	(3)	27,000	(3)
Thailand	849,500	(4)	15,006	(5)
China	827,500	(5)	15,000	(6)
Soviet Union	469,000	(6)	24,000	(4)
Zaire	463,000	(7)	1,500	(13)
Nigeria	399,100	(8)	1,100	(15)
Australia	293,400	(9)	9,000	(7)
Brazil	208,300	(10)	28,900	(2)
United Kingdom	113,900	(11)	4,000	(10)
Burma	92,000	(12)	939	(17)
South Africa	81,590	(13)	1,413	(14)
Japan	48,270	(14)	86	(27)
*East Germany	44,690	(15)	1,000	(16)
*Rwanda	41,890	(16)	N.r.	
Portugal	39,760	(17)	100	(26)
Zimbabwe	32,240	(18)	1,600	(12)
Argentina	30,220	(19)	300	(23)
*Laos	29,160	(20)	550	(20)
Namibia	28,460	(21)	600	(19)
Peru	27,640	(22)	5,000	(9)
*Spain	23,510	(23)	400	(21)
*Mexico	21,430	(24)	372	(22)
Canada	17,530	(25)	3,390	(11)
*Uganda	8,076	(26)	10	(28)
*France	7,775	(27)	N.r.	
*Czechoslovakia	6,618	(28)	250	(24)
Tanzania	6,080	(29)	2	(32)
*Vietnam	6,073	(30)	680	(18)
*Cameroon	4,423	(31)	9	(29)
United States	2,582	(32)	N.r.	
*Niger	2,347	(33)	110	(25)
*Italy	1,847	(34)	N.r.	
*Swaziland	1,794	(35)	N.r.	
*Burundi	979	(36)	N.r.	
*Morocco	962	(37)	N.r.	
*Congo	603	(38)	N.r.	
*South Korea	313	(39)	5	(30)
*Zambia	309	(40)	3	(31)
*Mozambique	94	(41)	N.r.	
Total	10,000,000		179,173	

[1] Data are not reported for all countries for every year. Because names of many countries have changed since 1934, modern names were used, and no account was made of boundary changes.

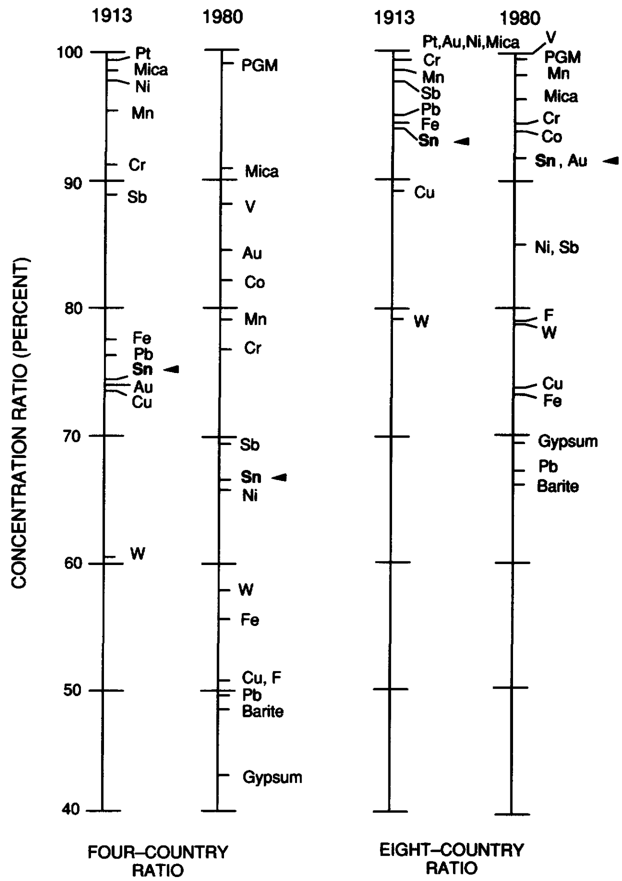


FIGURE 12. Concentration ratios (percentage of total production) for selected nonfuel mineral commodity production in 1913 and 1980 (modified from Scherer, 1970, p. 50–51). The ratios are percent of total world production for the indicated commodities, designated by chemical element symbols (PGM for platinum-group metals), for the four or eight countries having the largest reported production of the commodity in 1913 and 1980. (Sources of data: U.S. Geological Survey, 1921; U.S. Bureau of Mines, 1982.)

production, but Thailand was still recovering. Since reaching those highs, both the four-country and eight-country concentrations ratios have declined, and the price of tin has risen sharply.

By 1980, the four largest tin-producing countries, Malaysia, Thailand, Indonesia, and Bolivia, produced only 67 percent of total production; the eight largest tin producers that year, including the Soviet Union, China, Australia, and Brazil, produced less than 90 percent of the world's tin; and the average price of tin had risen to $18,650 per metric ton—a price that encouraged countries not restricted by quotas to produce more tin.

In 1986, the year after the collapse of the tin market, the four leading tin-producing countries, Malaysia, Brazil, the Soviet Union, and Indonesia, had 56 percent of world production, and the eight largest producers, including Bolivia, Thailand, China, and Australia, had declined to less than 85 percent.

TABLE 6.—*Estimated cumulative and annual mine production of tin, contained in ore and concentrate, by economic class for countries having reported production from 1934 through 1987*

[Source: U.S. Bureau of Mines (1940–88) and Richard Levine (1987, oral commun.). Includes some countries that had tin production during the period but that are not included in the ISMI tin inventory. Figures are in metric tons of contained tin; numbers in parentheses denote production ranking of class. Figures may not add up to totals shown due to rounding]

Economic class[1]	Cumulative production 1934–87		Percent	Annual production 1987 (estimate)		Percent
Low-income	1,479,000	(3)	14.8	18,791	(4)	10.5
Lower middle-income	4,199,000	(1)	42.0	57,318	(2)	31.9
Upper middle-income	3,293,000	(2)	32.9	61,478	(1)	34.2
Industrial market	508,600	(5)	5.1	16,876	(5)	9.4
East European nonmarket	520,300	(4)	5.2	25,250	(3)	14.1
Total	10,000,000		100.0	179,713		100.0

[1] Based principally on GNP per capita and, in some instances, other distinguishing economic characteristics (World Bank, 1986, p. 180–181). Countries that had reported tin production from 1934 through 1987 are, by class (countries not in the ISMI inventory are in italics): low-income economies—Burma, *Burundi*, China, *Laos*, *Mozambique*, *Niger*, *Rwanda*, *Swaziland*, *Tanzania*, *Uganda*, *Vietnam*, Zaire; lower middle-income economies—Bolivia, *Cameroon*, *Congo*, Indonesia, *Morocco*, Namibia, Nigeria, Peru, Thailand, *Zambia*, Zimbabwe; upper middle-income economies—Argentina, Brazil, Malaysia, *Mexico*, Portugal, South Africa, *South Korea*; industrial market economies—Australia, Canada, *France*, *Italy*, Japan, *Spain, the United Kingdom, the United States; and eastern European nonmarket economies—Czechoslovakia, East Germany*, the Soviet Union. A sixth economic class, high-income oil exporters, is not listed because those countries did not have reported tin production from 1934 through 1987.

TABLE 7.—*Tin R1E resources in the world's major deposits and districts, listed by mining method and economic class of country*

[Figures are in metric tons of contained tin. Figures may not add to totals shown due to rounding. N.r.=none reported]

Economic class[1]	Mining method: Surface	Underground	Surface and underground
Low-income	510,000	1,563,000	N.r.
Lower middle-income	1,907,000	560,400	31,670
Upper middle-income	2,395,000	80,420	24,200
Industrial market	96,050	248,200	N.r.
Eastern European nonmarket	[2]150,000	[2]150,000	N.r.
Total	5,059,000	2,602,000	55,880

[1] Based principally on GNP per capita and, in some cases, other distinguishing economic characteristics (World Bank, 1986, p. 180–181.) A sixth economic class, high-income oil exporters, is not listed because those countries do not have identified major tin deposits.

[2] Estimate.

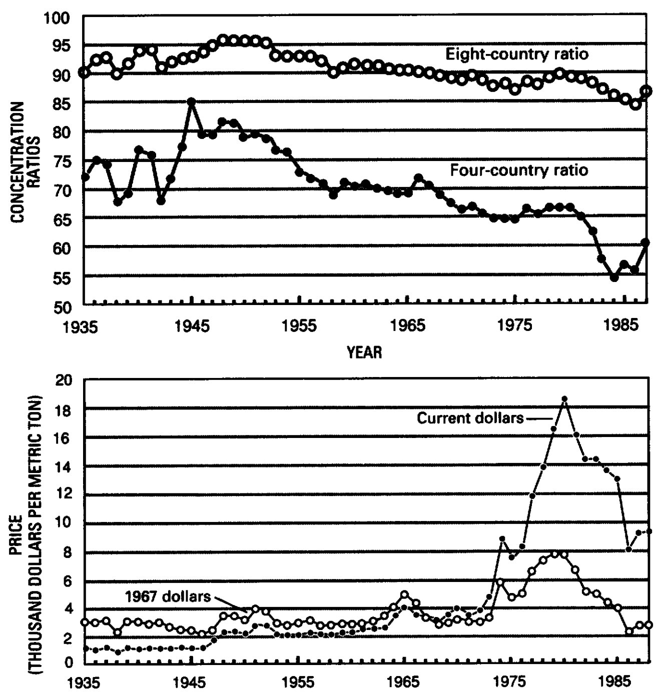


FIGURE 13. Tin concentration ratios and prices for the years 1935 to 1988. (Source: concentration ratios, available for 1935 to 1987, calculated from U.S. Bureau of Mines, 1946–88; prices, available for 1935 to June 1988, from Metallgesellschaft, 1961, p. 246; 1986, p. 428; and 1988, p. 455).

TIN CONSUMPTION

The contrast between tin-producing nations can be seen in tables 5 and 8 and in figure 14. Middle-income economy countries like Malaysia, Brazil, Indonesia, and Thailand have the greatest annual and cumulative production, yet they consume only a small part of the tin they produce. In 1987, the industrial market economy countries, such as the United States, Japan, and Germany, collectively consumed nearly 1,000 times more

TABLE 8.—*Estimated cumulative and annual apparent consumption of tin by major tin-consuming countries*

[Source: Metallgesellschaft, 1986, no. 73, p. 46–47, and 1988, no. 75, p. 44–45. Figures are in thousand metric tons of tin; numbers in parentheses denote ranking of country. N.r., not reported; N.a., not applicable]

Country	Cumulative consumption 1975–87		Annual consumption 1987	
United States	535.7	(1)	35.6	(1)
Japan	402.8	(2)	32.6	(2)
Soviet Union	345.5	(3)	29.0	(3)
West Germany	199.9	(4)	17.5	(4)
United Kingdom	151.9	(5)	9.8	(6)
China	136.5	(6)	13.5	(5)
France	114.2	(7)	7.4	(8)
Italy	70.1	(8)	6.0	(9)
Brazil	64.6	(9)	7.9	(7)
Netherlands	63.2	(10)	4.7	(11)
Canada	55.0	(11)	4.0	(12)
Spain	53.3	(12)	3.3	(15)
Poland	50.0	(13)	2.7	(17)
Czechoslovakia	45.0	(14)	3.1	(16)
East Germany	38.8	(15)	3.4	(14)
Australia	36.8	(16)	1.1	(27)
Romania	33.8	(17)	1.5	(24)
South Korea	33.7	(18)	5.8	(10)
India	33.2	(19)	2.6	(18)
Belgium-Luxembourg	30.2	(20)	1.4	(25)
South Africa	26.0	(21)	2.0	(21)
Taiwan	23.6	(22)	4.0	(12)
Mexico	22.1	(23)	2.5	(19)
Hungary	21.0	(24)	1.3	(26)
Bolivia	18.6	(25)	.3	(42)
Yugoslavia	16.6	(26)	1.1	(27)
Argentina	16.6	(26)	1.0	(30)
Hong Kong	14.3	(28)	2.5	(19)
Turkey	14.1	(29)	1.1	(27)
Bulgaria	12.6	(30)	2.0	(21)
Switzerland	9.9	(31)	.9	(31)
Portugal	9.7	(32)	.8	(33)
Thailand	9.3	(33)	1.9	(23)
Indonesia	8.1	(34)	.9	(31)
Philippines	7.9	(35)	.7	(35)
Greece	6.1	(36)	.6	(36)
Norway	6.0	(37)	.4	(40)
Austria	6.0	(37)	.5	(37)
Peru	5.6	(39)	.5	(37)
Sweden	5.4	(40)	.4	(40)
Venezuela	5.4	(40)	.8	(33)
Egypt	4.4	(42)	.2	(43)
Pakistan	3.6	(43)	.5	(37)
New Zealand	3.0	(44)	.2	(43)
Denmark	2.1	(45)	N.r.	
Finland	1.8	(46)	.1	(45)
Others	79.5	N.a.	5.1	N.a.
Total	2,853.5		227.2	

tin than they produced. The Soviet Union, the only eastern European nonmarket economy country having a deposit in the tin inventory, ranked third in production in 1987. In 1987, it consumed about 5,000 metric tons more than it produced. As a group, the low-income economy countries, such as Burma, China, and Zaire, produce somewhat more tin than they consume. A joint study by the U.S. Bureau of Mines and the U.S. Department of Commerce (1986) noted that U.S. tin consumption from 1972 decreased at a compound annual rate of 5.4 percent and would continue to decline from 1982 to 1993 at a compound annual rate of 3.2 percent.

Figure 15 illustrates where the current tin producers are and, from a resource standpoint, those deposits that will likely be producing tin in 2025. Decreases in production from certain deposits (for example, the Cornish lodes and lode deposits in Bolivia) may be replaced by production from present major suppliers such as Brazil or China or from currently inactive deposits in Australia such as Mount Bischoff, Doradilla, and Gillian. For example, Gillian's ability to become a tin producer would be largely due to a future technological breakthrough that would allow economical recovery of tin from stanniferous goethite in addition to fine-grained cassiterite. Research into extractive metallurgy on tin-skarn mineralogy, in which the tin may be present in silicate or borate minerals that are not presently amenable to normal recovery methods, would likely improve the resource outlook for this type of deposit. Lode deposits, such as Dachang and Gejiu in China and Renison in Australia, could be producing at that time, as would the placer deposits in the Southeast Asian Tin Belt. Pitinga, the world's largest tin producer and one of the few operations to be making money when the price of tin was most strongly depressed (Mayo, 1988), should continue to be a leading producer through 2025.

CONCLUSIONS

Tin is considered a strategic mineral commodity because of its use in tinplate and as a solder in electronics products and its utilization in tin chemicals and in alloys with other metals. In most of these cases, other metals such as aluminum or plastics can substitute for tin but with a loss of performance and (or) an increase in cost. As a secondary source, recycling provides tin for chemicals and solder to reduce dependency on primary production.

Until recently, International Tin Agreements between producing and consuming nations controlled the price and supply stability of the tin market. Tin deposits are of two basic types—lodes and placers. Lodes are generally mined at relatively high cost by underground methods, while placers are mined from the surface. Southeast Asia, Brazil, and China contain the major part of the world's tin resources.

Industrial market economy countries consume about three-quarters of the tin produced each year,

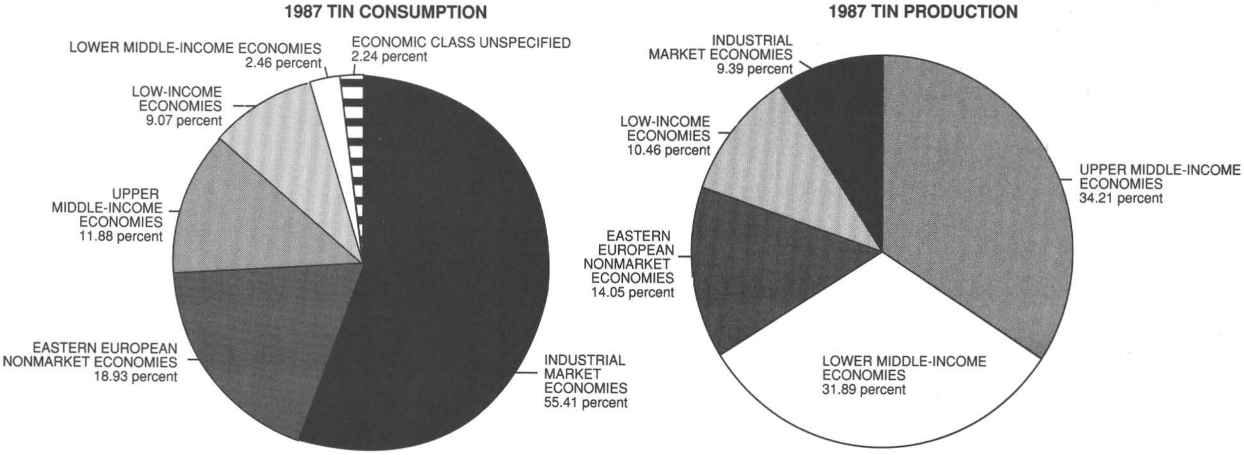


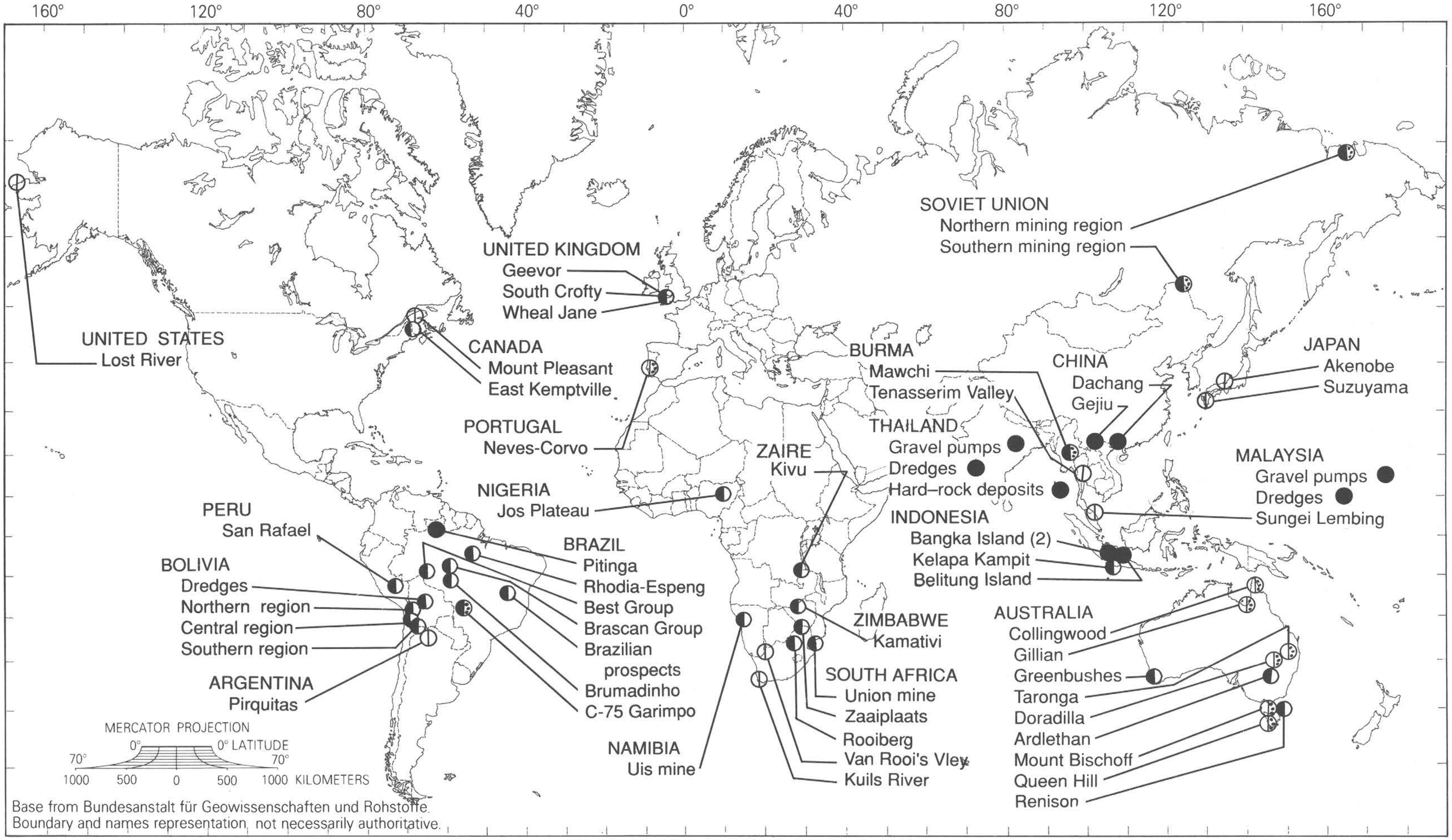
FIGURE 14. Tin production and consumption in 1987 by economic class of country (World Bank, 1986, p. 180–181; Carlin, 1987, p. 972; and Metallgesellschaft, 1984, p. 5).

whereas low- and middle-income economy countries account for most of that production. Since 1934, the low- and middle-income economy countries have accounted for about 90 percent of the world's tin production. Over the last 3 decades, mining and smelting operations in several tin-producing nations have been taken over by the government, thereby reducing private ownership, establishing local control, and reducing the participation of industrial market economy countries in tin production.

The first postwar International Tin Agreement of 1953 established the International Tin Council. When first established, the objectives of the Tin Council were to maintain price and supply stability. These objectives were accomplished through six International Tin Agreements, by buying tin in the world market through a buffer stock to maintain an established price. This approach, in turn, necessitated periodic export quota's on producing ITC members to limit tin supply. Despite these measures, a waning demand for tin in the late 1970's and early 1980's (in part due to artificially high tin prices), coupled with the emergence of Brazil as a major non-ITC producer, led to a tin glut. The Buffer Stock Manager made large purchases of tin to remove the excess supplies. In October 1985, the Buffer Stock Manager's funds were exhausted, trading was suspended, the tin council and prices collapsed, and about 100,000 metric tons of tin stocks remained.

Since collapse of the ITC, the most important factors in the short-term forecast for the future of tin are the rate of disposal and the level of tin stocks. In February 1989, the stocks had been reduced to 30,550 metric tons from 73,000 metric tons in March 1987, when the Association of Tin Producing Countries started supply controls (Mining Journal, 1989b). As these stocks are depleted, consumption and supply will take on greater significance. When the stocks are consumed, the future demand for tin will depend on how the tinplate market has changed in response to lower prices.

Brazil, presently the world's lowest cost and leading producer, will continue to have a profound effect on the tin market, as will China. Low-cost operations in the Southeast Asian Tin Belt and in Africa will remain competitive, but high-cost underground producers such as Japan, Bolivia, and perhaps the United Kingdom will likely close or require government subsidization.



EXPLANATION

- ● Active or intermittent producer in 1988; probably a significant producer in 2025.
- ◐ Active or intermittent producer in 1988; probably an insignificant producer in 2025.
- ◐ Active or intermittent producer in 1988; information insufficient to permit any forecast as to future production.
- ⦶ No production in 1988 or 1988 production not reported; probably an insignificant producer or exhausted by 2025.
- ⦶ No production in 1988 or 1988 production not reported; information insufficient to permit any forecast as to future production.

FIGURE 15. Major tin deposits and districts, their present production status, and their probable production status in 2025. Numbers in parentheses indicate the number of records (deposits and districts) for each location. Location names are from the tables in Part II.

PART II—SELECTED INVENTORY INFORMATION FOR TIN DEPOSITS AND DISTRICTS

Tables 9 and 10 contain information from the International Strategic Minerals Inventory record forms for tin deposits and districts. Only selected items of information about the location and geology (table 9) and mineral production and resources (table 10) of the deposits are listed here; some of this information has been abbreviated.

Summary descriptions and data are presented in the tables as closely as possible to the way that they were reported in the inventory records. For instance, significant digits for amounts of production or resources have been maintained as reported. Data that were reported in units other than metric tons have been converted to metric tons for comparability. Some of the data in the tables are more aggregated than in the inventory records, such as cumulative production totals that for some mines have been reported by year or by groups of years. Some of the abbreviations used in the inventory records forms have been used in these tables; they are explained in the headnotes.

TABLE 9.—*Selected geologic and location information*

Abbreviations used throughout this table include:

—, Not reported on the ISMI record form

Ma, Million years

Ga, Thousand million years

Host rock includes some or all of the following items (separated by semicolons): main host rock type; formation name; and host rock age.

Age abbreviations and prefix:

Cenozoic	CEN	Carboniferous	CARB
Quaternary	QUAT	Pennsylvanian	PENN
Holocene	HOLO	Mississippian	MISS
Pleistocene	PLEIS	Devonian	DEV
Tertiary	TERT	Silurian	SIL
Miocene	MIO	Ordovician	ORD
Oligocene	OLIG	Cambrian	CAMB
Mesozoic	MES	Precambrian	PREC
Cretaceous	CRET	Proterozoic	PROT
Jurassic	JUR	Archean	ARCH
Triassic	TRI	Early	E
Paleozoic	PAL	Middle	M
Permian	PERM	Late	L

Site name	Latitude	Longitude	Deposit type	Host rock	Age of mineralization
			Argentina		
Pirquitas mine (Jujuy Province).	22°43′S.	66°29′W.	Lode, subvolcanic vein	Schist (metavolcanics); Acoyte formation; ORD.	—
			Australia		
Ardlethan (New South Wales).	34°20′S.	146°51′E.	Lode, breccia systems (plutonic)	Granitic breccia within biotite-rich S-type granite; Mine granite; LSIL. Greisen; Ardlethan granite; LSIL.	LSIL (417±2.5 Ma).
Collingwood (Queensland).	15°46′S.	145°15′E.	Lode, massive greisen systems.	Greisenized granite; Finlayson granite; PERM. Hornfelsed argillites; Hodgkinson formation; MDEV–L(?)CARB.	PERM
Doradilla (New South Wales).	30°20′S.	146°21′E.	Lode, skarn	Calc-silicate hornfels, garnet-clinopyroxene skarn, dolomite, marble skarn; Girilamgone beds; ORD. Leucoadamellite, quartz-feldspar porphyry?	—
Gillian (Queensland)	17°43′S.	145°03′E.	----do------------	Sedimentary rocks; basalt, chert; Mount Garnet formation; SIL–DEV. Granite, rhyolitic porphyry dikes; Elizabeth Creek granite; MCARB. Granodiorite; Hammond Creek granodiorite; PERM.	PERM
Greenbushes (Western Australia).	33°50′S.	115°59′E.	Lode, pegmatite	Pegmatite; Greenbushes pegmatite group; ARCH. Lateritized boulder, gravel, and sand deposits; Greenbushes formation; CEN.	ARCH (2.53 Ga)
Mount Bischoff (Tasmania).	41°25′S.	145°32′E.	Lode, carbonate replacement; alteration of quartz-orthoclase porphyry dikes.	Dolomite, dolomitic shale, quartzite; Mount Bischoff beds; PREC. Quartz-orthoclase dikes and sills; DEV.	DEV

from ISMI records for tin deposits and districts

Abbreviations for mineral names (after Longe and others, 1978, p. 63–66):

Albite	ALBT	Clay	CLAY	Malayaite	MLYT	Siderite	SDRT
Allanite	ALNT	Clinopyroxene	CLPX	Marcasite	MRCS	Silver	SLVR
Ankerite	ANKR	Columbite	CLMB	Marmatite	MRMT	Sphalerite	SPLR
Apatite	APTT	Cookeite	COKT	Miargyrite	MRGR	Spodumene	SPDM
Argentite	ARGT	Ferberite	FRBR	Mica	MICA	Stannite	STNT
Arsenopyrite	ARPR	Fluorite	FLRT	Molybdenite	MLBD	Stibnite	STBN
Barite	BRIT	Franckeite	FRCK	Monazite	MNZT	Sulfides	SLPD
Beryl	BRYL	Galena	GLEN	Muscovite	MSCV	Talc	TALC
Beryllium	BRLM	Garnet	GRNT	Orthoclase	ORCL	Tantalite	TNTL
Biotite	BOTT	Goethite	GTHT	Phosphate	PSPT	Tetrahedrite	TRDR
Bismuth	BSMT	Gold	GOLD	Polybasite	PLBS	Thorite	THRT
Bismuthinite	BSMN	Hematite	HMTT	Proustite	PRST	Titanite	TTNT
Bornite	BRNT	Ilmenite	ILMN	Pyrargyrite	PRRG	Topaz	TOPZ
Calcite	CLCT	Indite	INDT	Pyrite	PYRT	Tourmaline	TRML
Carbonate	CRBN	Jamesonite	JMSN	Pyrrhotite	PYTT	Wolframite	WLFM
Cassiterite	CSTR	Kaolin	KOLN	Quartz	QRTZ	Xenotime	XNTM
Cerargyrite	CRRG	Limonite	LMON	Scheelite	SCLT	Zinnwaldite	ZNWD
Chalcopyrite	CLCP	Magnetite	MGNT	Sericite	SRCT	Zircon	ZRCN
Chlorite	CLRT						

Tectonic setting	Local environment	Principal mineral assemblages	Comments	Reference
		Argentina—Continued		
Extension of Bolivian tin belt.	—	CSTR, QRTZ, PYRT; SLVR, ARGT, GLEN, SPLR, PRRG, MRGR, PLBS, PRST, CRRG.	Three generations of mineralization; cassiterite is chiefly in the first; silver is in the second and third generations.	Ross (1941), Velasco (1988).
		Australia—Continued		
Plutons on western margin of the Lachlan fold belt (Girilambone anticlinorial zone).	Late stage granite implaced in preexisting Ardlethan granite.	CSTR, SRCT, TRML, QRTZ, ARPR, FLRT; CSTR, TOPZ, SRCT, FLRT, COKT, TRML, ARPR, WLFM; CSTR, SRCT, TRML, QRTZ, PYRT, CLCP, SPLR, GLEN, CLRT.	Hydrothermal breccia pipes, greisens, and veins were created by emplacement of late-stage granite.	Clarke and others (1985).
Folded and faulted shallow marine shelf.	Greisen/vein development in volatiles-rich granite that has hornfelsed overlying sediments.	CSTR, SRCT, TRML, QRTZ	Deposit consists of a cupola with greisen cap and quartz-cassiterite veins with greisen borders.	Krosch (1985).
—	Exoskarn developed near contact of calcareous units with volatiles-rich porphyritic leucoadamellite.	CSTR, PYTT, PYRT; hydrated CSTR, CLAY, LMON; MLYT, CSTR, CLPX, grossular GRNT, BRNT, CLCP, SPLR, GLEN, ARPR, PYRT, BOTT, CLRT, TTNT, MGNT, FLRT, QRTZ.	Host rocks also include garnet-clinopyroxene skarn, dolomite, marble, sulfide skarn, and quartz-feldspar porphyry.	Plimer (1984).
Folded and faulted shallow marine shelf.	Localized limestones converted to Sn-W-F-bearing skarns near contact with Elizabeth Creek granite.	CSTR, Sn-GTHT, LMON, MGNT, HMTT.	Minerals are the weathered equivalent of sulfide-rich cassiterite, magnetite, Sn-bearing garnet.	Brown and others (1984).
Crustal formation by mafic volcanics and sediments.	Implacement of rare-earth pegmatite during shearing and metamorphism.	CSTR, Nb-TNTL, Sb-TNTL, SPDM, APTT, BRYL, TRML, ALBT, QRTZ, ARPR, GRNT, KOLN.	A complex rare-earth pegmatite with deep eluvial profile, alluvial concentrations, and with hard-rock resources for tin, tantalum- niobium, lithium, and beryllium.	Blockley (1980).
West-southwest-trending PREC antiformal structure from overturned and isoclinally folded sequence.	Mineralization with the Mt. Bischoff beds as replacement. Alteration of porphyry dikes/sills intruded near crest of antiformal flexure.	Carbonate replacement: CSTR, PYTT, ARPR, TALC, QRTZ. Altered porphyry: CSTR, PYTT, ARPR, TOPZ, QRTZ.	Quartz-orthoclase dikes/sills were altered by fluids that replaced the adjacent dolomitic units.	Collins (1986).

Table 9.—*Selected geologic and location information*

Site name	Latitude	Longitude	Deposit type	Host rock	Age of mineralization
			Australia—Continued		
Queen Hill deposits (Tasmania).	41°54′S.	145°18′E.	Lode, carbonate replacement.	Evaporitic carbonate, pyritic mudstone; Oonah quartzite; PROT. Volcaniclastic wacke, shale; Crimson Creek formation; CAMB. Dolomite, sandstone; Success Creek group; LCAMB.	DEV
Renison (Tasmania)	41°47′S.	145°26′E.	Lode, carbonate replacement.	Dolostone, quartzite, siltstone; Success Creek group; ECAMB. Dolostone, siltstone, shale, sandstone; Crimson Creek formation; ECAMB. Fault infill; DEV.	----do-----------
Taronga (New South Wales).	29°27′S.	151°32′E.	Lode, stockwork/sheeted veins.	Mudstone, siltstone, sandstone (hornfelsed); LPERM–CARB.	LTRI?
			Bolivia		
Bolivian central region deposits (Morococala district).	19°S.	66°W.	Lode, subvolcanic	Slate, metasediment, volcanics; Llallagua, Unica, Pampa, Cerro Rico formations; ORD–LTERT.	TERT
Bolivian dredges	18°S.	65°W.	Placer, alluvial	Sediments; QUAT	—
Bolivian northern region deposits (Morococala district).	19°S.	66°W.	Lode, vein	Granodiorite; TERT. Quartzite, shale; PAL.	TERT
Bolivian southern region	19°S.	66°W.	Lode, subvolcanic	Llallagua formation; PAL–TERT	----do-----------
			Brazil		
Best Group (Rondônia and Pará States).	09°27′S.	65°08′W.	Placer, gravel pump	Greisen; PREC. Paleovalley sediments.	—
Brascan Group (Rondônia tin province).	09°S.	63°W.	Placer, gravel pump; Lode, massive greisen.	Granite; Rapakivi granite; PREC. Paleovalley sediments.	—
Brazilian prospects (Pará and Goiás States).	Serra Branca: 13°37′S. 48°04′W.	Mocambo: 06°50′S. 51°57′W.	----do------------	Grupo Araxá; PREC. Grupo Arai; PREC. Granitized quartzites; PREC.	PREC

Tectonic setting	Local environment	Principal mineral assemblages	Comments	Reference
Australia—Continued				
Shallow to deeper water trough sedimentation (Dundas trough).	Broad folding and faulting. Faults act as loci of mineral fluids plumbed up from concealed DEV granite.	Queen Hill and Montana deposits—CSTR, PYRT, SDRT, CLRT, QRTZ, SPLR, GLEN, STNT, Ag sulfosalts. Severn deposit—CSTR, PYTT, PYRT, SDRT, QRTZ, SPLR, GLEN, STNT, Ag sulfosalts; CSTR, PYRT, QRTZ veins; STNT, PYRT, CLCP, QRTZ veins.	Clarkes lode was discovered in 1895 and the cassiterite+pyrite association in 1965.	Anderson (1986).
Within gently folded Dundas trough (ECAMB–CARB?).	Mineralization within both east limb of broad anticline and truncating eastern fault; other block faulting is present.	CSTR, PYTT; CSTR, PYTT, ARPR, PYRT, CSTR, QRTZ, ARPR, PYTT, TRML.	Replacement of parts of dolomitic units adjacent to and within faults which acted as solution pathways.	Morland (1986).
Marine sediments of the New England fold belt (back arc environment?).	LTRI adamelllite intrusion underlies stockwork veins along an anticlinial axis.	CSTR, QRTZ, CLCP, ARPR, FLRT, TOPZ, MSCV.	Vertical vein swarms and mineralized joints with muscovite selvages.	Offenberg (1982).
Bolivia—Continued				
Bolivian cordillera.	—	CSTR, BSMN, SPLR, STNT, FRCK, CLCP, PYRT, MRCS, SDRT, hydrous phosphates, BRIT.	Stockwork of TERT intrusives and breccia pipes. Sericitic alteration, tourmalization, and silicification are present.	Fox (1971), Sillitoe and others (1975).
----do----------	Lipez Huayco and Antequera riverbeds.	CSTR, HMTT, MGNT, ILMN, TRML, QRTZ.	Includes Comsur, Estalsa, and El Centenario dredges.	Do.
----do-----------	—	CSTR, PYRT, BSMN, CLCP, ARPR, WLFM, CLCT, HMTT, SDRT, GLEN.	Sericite, chlorite, tourmaline, and greisen-type alteration have been identified.	Do.
----do-----------	Avicaya anticline	CSTR, BSMT, SPLR, STNT, FRCK, CLCP, PYRT, MCSV, SDRT, hydrous phosphate.	Tertiary intrusives, breccia pipes, and sericitic alteration occur throughout the stockwork. Tourmalization and silification are at Avicaya.	Do.
Brazil—Continued				
PREC shield	Paleovalley placers	CSTR, TOPZ, TRML, XNTM, CLMB, PSPT, GOLD, ILMN.	Exploration continues at São Sebastiao deposit and in Rondônia and Para States in general.	Bettencourt and others (1981).
----do-----------	----do-----------	CSTR, TOPZ, MSCV.	Includes Santa Barbara, Taboquinha, Nova Mundo, Poco, Cortez, Candeias, Potosi (alluvial), Potosi (alluvial), Potosi Hill (lode), Duduca, and Jacundá mines and deposits. Potosi Hill is minor. This record reflects only alluvial deposits.	Mareno (1986).
Stable craton, PREC shield.	—	TRML, FLRT, BRYL, CSTR, ZNWD, CRBN.	Includes Serra Branca deposit and Mocambo project. Autochthonous deposit; greisenized or granitized. PREC intrusives, sediments, and extrusives are at Serra Branca.	—

Table 9.—*Selected geologic and location information*

Site name	Latitude	Longitude	Deposit type	Host rock	Age of mineralization
			Brazil—Continued		
Brumadinho Group (Rondônia and Goiás States).	09°33′S.	62°25′W.	Placer and lode	Granite; Rapakivi granite; PREC. Schists and granites; Grupo Araxá, Grupo Arai; PREC. Paleovalley fill.	—
C–75 Garimpo (Rondônia State).	09°54′S.	63°26′W.	Placer, eluvial; lode, greisen and vein.	Granite; Rondônia granite suite; EPROT–MPROT (1,150–925 Ma). Gneiss, basement rocks; Xingu complex; EPROT–MPROT (>1,500 Ma).	EPROT–MPROT (1,150–925 Ma).
Paranapanema group Pitinga (Mapuero tin district, Amazonas).	00°45′S.	60°07′W.	Placer, onshore dredge	"Apogranite"; Madera granite; MPROT (1.9–1.5 Ga). Rhyolite and tuffs; MPROT.	MPROT
Rhodia-Espeng (Pará State).	06°02′S.	53°43′W.	Placer, gravel pump	Granite (source); Velho Guilherme type granite; PREC?. Granite (source); Maloquinha intrusive suite; PREC?.	—
			Burma		
Mawchi mine (Kayah Province).	18°49′N.	97°10′E.	Lode, vein	Clastic and carbonate metasediments; Mawchi series; CARB (MISS-PENN). Granite; Mawchi granitoid pluton; LMES-ETERT.	—
Tenasserim Valley (Southeast Asian Tin Belt).	12°N.	99°E.	Placer (alluvial)	Eluvial and alluvial sediments; Mergui series; CARB. Granite (tourmaline-rich); LMES.	—
			Canada		
East Kemptville (Nova Scotia).	44°06′N.	65°41′W.	Lode, greisen	Granite; Davis Lake Complex; LDEV-ECARB.	LCARB (295±5 Ma, Ar-Ar).
Mount Pleasant (New Brunswick).	45°26′N.	66°49′W.	Lode, subvolcanic vein/porphyry.	Granite; LMISS (340–330 Ma, Rb-Sr). Breccia; LMISS. Quartz-feldspar porphyry; LMISS (340–330 Ma, Rb-Sr).	MISS (340–330 Ma, K/Ar, W, Mo, Bi). MISS (340–330 Ma, K/Ar, Sn, base metals).
			China		
Dachang tin field (Guangxi Province).	24°50′N.	107°50′E.	Lode, carbonate replacement.	Shale, marl, limestone; MDEV–LPERM. Granite (source rock); Longxianggai biotite granite; CRET (107 Ma, K/Ar).	CRET (107 Ma); CRET (97 Ma).

from ISMI records for tin deposits and districts—Continued

Tectonic setting	Local environment	Principal mineral assemblages	Comments	Reference
		Brazil—Continued		
PREC shield	Paleovalley concentrations of cassiterite and other resistate minerals.	CSTR, TRML, FLRT, ILMN	Includes the following producing deposits: Oriente Novo, Cachoeirinha, São Domingos, and São Lourenço; and several nonproducing deposits.	Mareno (1986).
—	—	CSTR, QRTZ	The deposit falls on the edge of a circular topographic feature. Almost every tin deposit in that part of Rondônia is associated with a ring structure or a circular pluton.	Thorman and Drew (1988).
PREC shield	Paleovalley concentrations of cassiterite and other resistate minerals.	CSTR, ZRCN, PCLR, CLMB, TNTL, XNTM.	Paranapanema's largest deposit, by far, is the Pitinga deposit. In 1988, 19 dredges operated there.	Mareno (1986), Thorman and Drew (1988).
—	—	CSTR, WLFM, CLMB, MNZT, ZRCN, TRML.	Located on the Igarapé de Bala, in the Iriri River region, west of the Xingu River.	—
		Burma—Continued		
—	Intrusion of Mawchi granitoid pluton.	CSTR, WLFM, PYRT, CLCP, SCLT	More than 60 major veins are in the mine. Vein strike 6–60 °NE., dip 75–80 °W. Maximum length is 570 m, and average thickness is 1 m. Tin mineralization is found down to 300 m.	Khin and Thet (1983).
—	Southeast Asian Tin Belt.	CSTR, WLFM, BSMN, MGNT, PYRT	Deposits are similar to those in Malaysia and Thailand but not as large; the terrain in Burma is not favorable to the formation of large placer deposits.	—
		Canada—Continued		
LPAL orogenic belt (Hercynian).	LDEV–ECARB epizonal granite batholith that intruded CAMB-ORD clastic metasedimentary rocks.	CSTR, QRTZ, MSCV, TOPZ, PYRT, PYTT, SPLR, CLCP, ARPR, WLFM, FLRT.	Deposit consists of tin-rich, greisen-altered granite, adjacent to fractures and quartz veins, and under 3–5 m of glacial till.	Richardson and others (1982).
LPAL orogenic belt.	Volcanic center on the margin of a MISS caldera.	CSTR, FLRT, TOPZ, QRTZ, CLRT, ARPR, CLCP, PYRT, SPLR, GLEN, STNT, WLFM.	Cassiterite occurs in veins and as disseminated grains and clusters in greisen-altered granite and associated quartz-feldspar porphyry and breccia.	Kooiman and others (1986).
		China—Continued		
On NW border of Shan tectonic belt, SE of the pre-Sinian Chianganian shield.	NW–SE trending anticlinorium parallel to a major fault system and characterized by large overthrust structures.	CSTR, PYTT, MRMT, PYRT, JMSN, CLCP, GLEN, STBN, FLRT.	At least nine ore bodies are known at Dachang. At Changpo mine, mineralization is known to a depth of 500 m. China's tin industry is plagued with a lack of water, electricity, and facilities.	Premoli (1986).

Table 9.—*Selected geologic and location information*

Site name	Latitude	Longitude	Deposit type	Host rock	Age of mineralization
			China—Continued		
Gejiu district (Yunnan Province).	23°20′N.	103°20′E.	Lode, carbonate replacement, some vein-type skarn.	Limestone and dolomite with minor argillite, tuff and basalt; MTRI. Gneiss and schist (bedrock); PREC. Biotite granite (intrudes the limestone); CRET (115–64 Ma, K/Ar).	115–84 Ma (K/Ar) porphyritic biotite granite. 80–64 Ma (K/Ar) equigranular biotite granite.
			Indonesia		
Kelapa Kampit mine (Belitung).	02°45′S.	108°05′E.	Lode, vein	Quartzites, sandstones, slates; PERM. Granitoids; MES.	LTRI
P.T. Tambang Timah—Bangka (Bangka).	02°S.	106°E.	Placer, gravel pump, and onshore dredge.	Alluvial and eluvial sediments; post-TRI.	—
P.T. Tambang Timah—Belitung (Belitung).	02°40′S. 107°50′E.	----do------	----do-----------	—	—
P.T. Koba Tin (Bangka)	02°35′S.	106°24′E.	Placer, gravel pump, and dredge.	Detrital sediments	—
			Japan		
Akenobe mine (Hyōgo Prefecture, Honshū Island).	35°13′N.	134°41′E.	Lode, polymetallic vein	Slate; Setani formation (Maizuru group); LPERM. Basalt, basaltic tuff, and phyllite; Surugamme formation (Maizuru group); LPERM.	TERT?
Suzuyama mine (Kyūshū Island).	31°30′N.	130°26′E.	Lode, pegmatite and quartz veins.	Granite; TERT. Pegmatite; LMES–ETERT. Shale and sandstone; MES.	TERT
			Malaysia		
Malaysian dredges (Southeast Asian Tin Belt).	04°N.	103°E.	Placer, onshore dredge	Alluvium; QUAT. Granite; MES. Sediments; PAL.	—
Malaysian gravel pump mines (Southeast Asian Tin Belt).	04°N.	103°E.	Placer, gravel pump	Alluvium; QUAT. Granite; MES. Limestones, sandstones, metasediments; PAL.	—
Sungei Lembing (Southeast Asian Tin Belt).	03°52′N.	103°05′S.	Lode, vein	—	CARB
			Namibia		
Uis tin mine (Southern Damaraland).	21°13′S.	14°52′E.	Lode, altered pegmatite	Quartzitic schist; Kuiseb formation, Swakop group; MPROT (720–650 Ma). Pegmatite; Namibian pegmatite.	Unknown

from ISMI records for tin deposits and districts—Continued

Tectonic setting	Local environment	Principal mineral assemblages	Comments	Reference
China—Continued				
Yunnan Arc—east-trending and northeast-trending mountain ranges.	Two mountain ranges come together at Gejiu, and two systems of faults cross the ranges.	CSTR, MLBD, WLFM, BSMN, ARPR, PYRT, HMTT, MGNT, GLEN, SPLR. Gangue: QRTZ, TRML, TOPZ, Li-MICA, FLRT.	Tin deposits are along anticlines or above granite cupolas. Gejiu has been called the largest tin-skarn dominated district in China.	Kwak (1987).
Indonesia—Continued				
Steeply dipping sediments associated with large-scale fold closures.	Northeast to southwest faults and associated north and south fissures.	CSTR, MGNT, ILMN, ZRCN, MNZT	PERM sediments of Belitung Island are underlain by MES plutonic rocks. Tin-bearing granites are the source of the mineralized veins.	Omer-Cooper and others (1974).
—	—	CSTR, TNTL, ILMN, ZRCN	Cassiterite concentrations are found in ancient and modern placers.	—
—	—	CSTR, TRML, TOPZ, ILMN, ZRCN	----do-----------	Prijono (1986).
—	—	CSTR, MNZT, ILMN, ZRCN, XNTM, TRML.	Placers formed in current and ancient channels. Offshore extensions are believed to be of near-shore deposits flooded by post-PLEIS sea-level increases.	Do.
Japan—Continued				
Island arc	Maizuru structural belt	CSTR, SPLR; WLFM, MGNT, PYRT; QRTZ, CLCT, FLRT, CLRT.	Cited as an example of a xenothermal deposit. Over 100 veins are known. Xenothermal deposits are the most important tin deposits in Japan.	Sato and Akiyama (1980).
----do-----------	—	CSRT, PYRT, SPLR, GLEN, QRTZ	Pegmatite veins occur in Mesozoic shale and sandstone that was intruded by a granite stock of Tertiary age.	Saito and others (1960).
Malaysia—Continued				
—	Postorogenic intrusive	CSTR, ILMN, MNZT, PYRT, ARPR, SDRT, QRTZ, WLFM, GOLD.	Erosion of greisen/vein lodes resulted in formation of placer accumulation of heavy minerals on trough and pinnacle structures formed by the older limestones.	Govett and Robinson (1980).
—	----do-----------	CSTR, ILMN, MNZT, ZRCN, ARPR, SDRT, QRTZ, WLFM, GOLD.	Erosion of greisen/vein lodes and subsequent placer accumulations in trough and pinnacle structures of older limestone.	Do.
----do-----------	Deeply weathered granite host.	CSTR, PYRT, CLCP, ARPR, SPLR, GLEN, PYTT.	Similar to the Cornwell tin deposits.	—
Namibia—Continued				
—	Damara orogenic belt	CSTR, ALBT, MSCV, SRCT, CLRT; TOPZ, GRNT, TRML, APTT.	Pegmatites are linear to sigmoidal, varying from small to large, and swelling in the middle before pinching out.	Richards (1986).

Table 9.—*Selected geologic and location information*

Site name	Latitude	Longitude	Deposit type	Host rock	Age of mineralization
			Nigeria		
Jos Plateau deposits. (Bauchi, Benue, Kano, and Zaria States).	09°45′N.	08°52′E.	Placer	Alluvium and eluvium; TERT–HOLO. Granite; Nigerian younger granites; JUR. Basalt; Newer basalts; QUAT.	JUR
			Peru		
San Rafael mine (Melgar Province).	14°12′S.	70°20′W.	Lode, vein	Volcanics, extrusives, breccias, and andesitic agglomerates. Granite; San Rafael stock; OLIG–MIO (25.9±1 Ma).	OLIG–MIO (22.6±0.5 Ma).
			Portugal		
Neves-Corvo mine (Baixo Alentejo Province).	37°36′N.	07°58′W.	Lode, massive sulfide	Volcanics; Pomarao group; DEV.	CARB
			South Africa		
Kuils River tin (Cape Province).	33°56′S.	18°44′E.	Lode, hydrothermal greisen veins.	Granite; Cape granite suite; CAMB (553±8 Ma). Malmesbury group; LPROT–CAMB (595±45 Ma).	CAMB (553±8 Ma).
Rooiberg tin mines (Transvaal).	24°45′S.	27°45′E.	Lode	Arkosic quartzite; Leeuwpoort formation; EPROT. Shaley quartzite and shale; Blaauwbank shale member; EPROT. Quartzite, andesite, arkosite, dolomite; Smelterskop quartzite formation; EPROT (about 2,100 Ma).	EPROT (about 1,960 Ma).
Van Rooi's Vley (Cape Province).	28°30′S.	20°53′E.	Lode, vein, stockwork, and replacement pipes.	Paragneiss; Toeslaan formation; MPROT.	LPROT (U/Pb: 940±50 Ma).
Union tin mine (Transvaal).	24°29′S.	28°30′E.	Lode, vein	Indurated tuff; Union tin tuff member; EPROT (about 2,300 Ma). Felsite (rhyolite); Rooiberg group EPROT (about 2,300 Ma).	EPROT (2,050 Ma).
Zaaiplaats tin mine (Transvaal).	24°03′S.	28°45′E.	Lode; veins, pipes, and disseminated ores.	Leuco-granite to mildly alkali granite; Bobbejaankop granite; EPROT (2,010–1,960 Ma). Granophyre; Rashoop granophyre suite; EPROT (about 2,120 Ma). Micro-granite; Lease granite; EPROT (2,010–1,960 Ma).	EPROT (1,960 Ma)
			Soviet Union		
Soviet Union southern mining regions (Chita, Khabarovsk).	53°N.	124°E.	Lode	Quartz porphyry granite; ECRET (109–105 Ma). Volcanic quartz porphyry tuff; LCRET (100–75 Ma).	LCRET (97–91 Ma).

Tectonic setting	Local environment	Principal mineral assemblages	Comments	Reference
		Nigeria—Continued		
Anorogenic granites in cratonic shield.	Younger granite province	CSTR, CLMB, minor WLFM, TNTL, THRT.	Tin mineralization occurs in the Younger granites. Placers are the most common deposits, but primary mines are known. Some alluvial deposits are under basalt sheets.	MacLeod and others (1971).
		Peru—Continued		
Andean tin belt	—	CSTR, CLCP, PYRT, QRTZ	Consists of several mineralized veins striking NW. for 1.5 km and dipping 70–75° south to a depth of 4,000 m.	Clark and others (1983).
		Portugal—Continued		
Eugeosynclinal	Submarine, flysch and volcanics in a subsiding basin.	PYRT, CLCP, GLEN, SPLR, CSTR, ARPR, TRDR, STNT, BSMN.	Discovered via gravity surveys. Polymetallic deposit has three types of ore: stockwork, massive, and banded.	Mining Journal (1988b).
		South Africa—Continued		
Late orogenic or post orogenic.	Plutonic and country rock veins.	CSTR, WLFM, TRML, CLCP, ARPR, MLBD.	Three types of tin deposits: endogranitic greisen veins; exogranitic stringer veins and lodes; and residual tin-wolframite scree.	Hill and Brunker (1981).
Intracratonic	Bushveld granite intrusion into Rooiberg group and Leeuwpoort/Smelterskop formations.	CSTR, ANKR, TRML, APTT, CLCP, ARPR, PYTT, SPLR, GLEN, BRNT, MGNT, SCLT, ORCL.	Ore is comprised of lodes and pockets in fractures and is often controlled by bedding displacement.	Rozendal and others (1986).
Intracratonic Kalahari Craton.	Ultra metamorphic/plutonic Gordonia subprovince, Namaqualand metamorphic complex.	SCLT, WLFM, CSTR, MLBD, QRTZ, TRML, FLRT.	Genetically related to regional ultra metamorphism and pegmatite and anatectic granite development.	von Backström (1950).
Intracratonic	Fractures in indurated tuff contain cassiterite.	CSTR, MGNT, PYRT, CLCP, CLRT, ANKR.	Mineralized only where fractures pass through Union tin tuff and not in sidewall of Rooiberg group rhyolite.	Pringle (1986).
----do------------	Monoclinal arch of plutonic fractionated granite.	CSTR, TRML, CLRT, QRTZ, FLRT, SRCT, SCLT, ARPR, CLCP, PYRT, GLEN, SPLR, ORCL.	Plutonic granite dome with three types of cassiterite mineralization: disseminated, lenticular greisen, and pipe-form.	Zaaiplaats Tin Mining Company (1983).
		Soviet Union—Continued		
—	Extrusion complex	CSTR, QRTZ, FLRT, GLEN, BSMT, SCLT, INDT.	Regions include Khaborovskiy Kray, Primorskiy Kray, and Chita Oblast and the following deposits: Khingan, Olonoi, Berezovo, Dzhalinda, Obeshayushchee, Lesnoe, Verkhnee (upper), and Nizhnee (lower).	Smirnov (1977).

TABLE 9. *Selected geologic and location information*

Site name	Latitude	Longitude	Deposit type	Host rock	Age of mineralization
			Soviet Union—Continued		
Soviet Union northern mining regions (Magadan Oblast and Yakut, ASSR).	69°N.	140°E.	Lode, vein	Sandstone and siltstone; JUR. Granite; LJUR (143–138 Ma, K/Ar on biotite).	LJUR (143–138 Ma).
			Thailand		
Thai dredging operations (Southeast Asian Tin Belt).	09°N.	99°E.	Placer, dredge	Alluvial and eluvial; Pre-PLEIS. Granite; CRET–TERT. Granite, TRI.	CRET
Thai gravel pump operations (Southeast Asian Tin Belt).	08°N.	99°E.	Placer, gravel pump	Detrital sediments; Pre-PLEIS. Granite; CRET–TERT. Granite; TRI.	TRI, CRET
Thai hard-rock and open-cast operations (Southeast Asian Tin Belt).	13°52′N.	99°07′E.	Lode	Granite; CRET–TERT	CRET
			United Kingdom		
Geevor mine (St. Just mining district).	50°09′N.	05°41′W.	Lode, vein	Slate; Killas slate; DEV (about 360 Ma). Granite; Lands End granite; CARB (300±10 Ma, K/Ar, Rb/Sr, U/Pb).	CARB (270±5 Ma, K/Ar, Rb/Sr, U/Pb). TRI (215±5 Ma, K/Ar, Rb/Sr, U/Pb).
South Crofty mine (Camborne, Redruth mining district).	50°14′N.	05°17′W.	----do-----------	Granite; Carn Brae granite; CARB (300±10 Ma, K/Ar, Rb/Sr). Slate; Killas slate; DEV (about 360 Ma).	CARB (270±5 Ma, U/Pb). TRI (215±5 Ma, U/Pb).
Wheal Jane (St. Day mining district).	50°14′N.	05°07′W.	----do-----------	Slate; Killas slate; DEV (330 Ma). Quartz porphyry inclined dikes; Elvans formation.	CARB (270±10 Ma). TRI (215±5 Ma).
			United States		
Lost River district (Alaska).	65°29′N.	167°08′W.	Lode, vein, greisen, skarn.	Rhyolite porphyry dike; cassiterite dike; CRET–TERT. Limestone; Port Clarence limestone; EORD–MORD. Granite; LCRET (K/Ar on biotite).	LCRET
			Zaire		
Kivu mines (Maniema-Kivu area).	26°00′S.	27°30′E.	Placer, gravel pump	Alluvium and eluvium. Granite. Metasedimentary basement.	PREC
			Zimbabwe		
Kamativi tin mines (Wankie).	17°30′S.	27°07′E.	Lode, pegmatite	Tin pegmatite. Schist; Kamativi schist belt; PREC.	PREC

from ISMI records for tin deposits and districts—Continued

Tectonic setting	Local environment	Principal mineral assemblages	Comments	Reference
		Soviet Union—Continued		
Polousnaya mega-synclinorium.	Intrusion of granite into TRI–JUR terriginous sediments.	CSTR, CLRT, QRTZ; CSTR, CLRT, SLPD; CSTR, TRML, SLPD, QRTZ.	Much of the data here is for Deputat deposit, which consists of 150 ore bodies.	Smirnov (1977).
		Thailand—Continued		
Island arc	Lateritic weathering of granites and pegmatites.	CSTR, ILMN, TNTL, ZRCN, ALNT, SCLT, MNZT, SDRT, GRNT, TRML.	Sn, W, and occasionally Ta mineralization is associated with TRI and CRET-–TERT granites.	—
----do-----------	—	CSTR, GRNT, TNLT, WLFM, SCLT.	Many deposits include tantalite that is recovered. Some greisen zones within CRET granites contain large amounts of wolframite.	Nutalaya and others (1979).
—	—	CSTR, GRNT, ILMN, TNTL, TOPZ, FLRT, TRML, APTT.	Yala Province deposits occur at contact of LPAL sediments and CRET granite. Mineralization occurs almost exclusively within the sediments with minor veining extending from the granite source rock.	—
		United Kingdom—Continued		
Hercynian orogenic belt.	Transverse lodes adjacent to granite contact.	QRTZ, TRML, CSTR.	Vein outcrop in sea cliff faces.	Dines (1956).
----do-----------	Lodes within granite, often close to margin.	QRTZ, TRML, CLRT, HMTT, ARPR, CLCP.	—	Do.
----do-----------	One major lode, adjacent to quartz-porphyry dikes.	QRTZ, TRML, CLRT, SPLR, ARPR, PYRT, CLCP, FLRT, CSTR.	—	Do.
		United States—Continued		
Postorogenic granites in fold/thrust belt.	Lodes adjacent to or within tin granite and associated dikes.	CSTR, STNT, WLFM, SLPD; QRTZ, TOPZ, MICA.	Badly kaolinized rock makes mining more costly; clay coats cassiterite grains making milling inefficient; small placers.	Sainsbury (1970).
		Zaire—Continued		
—	—	CSTR, minor WLFM, Nb-TNTL, FRBR, MNZT.	Primary deposits are accessible after 1 m alluvial and 3 m eluvial deposits are removed.	Angermeier and others (1974).
		Zimbabwe—Continued		
—	Kamativi schist belt.	CSTR, TNTL, Li-minerals, trace BRLM; TRML, QRTZ, ALBT.	—	Bellasis and van der Heyde (1962); Rijks and Van de Veen (1972).

TABLE 10.—*Selected production and mineral-resource information*

Abbreviations used throughout this table include:
—, Not reported on the ISMI record form
t, Metric tons
g/t, Grams per metric ton
Abbreviations for *mining method*: S, surface; U, underground; N, not yet producing.
Annual production includes some or all of the following items (separated by semicolons): Production in metric tons of material mined (unless other processing stage is indicated); grade of reported material; and year of production (or range of years used to estimate average annual production).

Site name	Year of discovery	Mining method	Year of first production	Materials of economic interest
		Argentina		
Pirquitas mine (Jujuy Province)	1932	U	1964	Sn, Ag
		Australia		
Ardlethan (New South Wales)	1912, 1964	S, U	1912 (minor), 1964 (major).	Sn
Collingwood (Queensland)	1885, 1980	N	None	Sn
Doradilla (New South Wales)	1974 (Sn)	N	None	Sn, Cu, Pb, Zn
Gillian (Queensland)	1974	N	None	Sn
Greenbushes (Western Australia)	1888	S (placer)	1888 (1964 dredging).	Sn, Ta, Nb, Li, kaolin
Renison (Tasmania)	1890	U	1962	Sn
Mount Bischoff (Tasmania)	1871	S	1871	Sn
Queen Hill deposits (Tasmania)	1895, 1965	N	None	Sn, Pb, Zn, Ag

from ISMI records for tin deposits and districts

Cumulative production includes some or all of the following items (separated by semicolons): production in metric tons of material mined (unless other processing state is indicated); grade of reported material; and years for reported cumulative production.

Resources includes, for various resource categories, some or all of the following items (separated by semicolons): resource in metric tons; U.N. resource classification (United Nations Economic and Social Council, 1979; Schanz, 1980); grade (unless resource is specified as contained metal); and year of estimate. Grades reported for mining properties often are the grade of mill feed, while for undeveloped properties, in-place grades are usually reported. Dilution in the mill feed grades may be about 15 percent for underground mining.

Annual production	Cumulative production	Resources	Comments
		Argentina—Continued	
600; contained Sn; 1984. 130,000; ore (annual capacity).	—	—	New smelter/refinery complex to be built on site will reduce production costs and transportation costs of concentrates.
		Australia—Continued	
450,000; 0.47 percent Sn (mill head); 1972–86	14,000; contained Sn; 1912–73. 25,000; contained Sn; 1964–86.	3,000,000; R2S; 0.5 percent Sn; 1980. 1,000,000; R2S; <0.5 percent Sn; 1981.	Closed in 1986. Deep low-grade ore bodies and tailings may warrant reassessment when market improves.
None	None	4,000,000; R2S; 0.73 percent Sn; 1984?.	Results of a 1985–86 feasibility study are not known.
None	None	10–12,000,000; R2S; 0.3 percent Sn; 1978. 1,800,000; R2S; 0.7 percent Sn; 1983. 3,900,000; R2S; 0.6 percent Sn; 1984 (revision of 1983 estimate).	1983 resource estimate is for 10 percent of strike length with a 50-m depth limit. 1984 estimate includes more strike length.
None	None	2,300,000; R1S; 0.81 percent Sn; 1982.	Complex metallurgy, very fine grained cassiterite and tin in goethite/limonite.
351.3; 99.7 percent Sn; 1985. 97,200; 100 percent Ta_2O_5; 1985. 11,835; 7 percent Li_2O; 1985.	17,689 (Sn concentrates); 1889–1975.	8,812,000; R1E; 0.0268 percent Sn, 0.00369 percent Ta_2O_5; 1985 (soft-rock ore). 2,142,000; R1E; 0.06 percent Sn, 0.0045 percent Ta_2O_5; 1985 (tailings). 41,900,000; R1E, 2.92 percent Li_2O; 1986 (spodumene ore). 38,970,000; R1S; 0.1175 percent Sn, 0.044 percent Ta_2O_5; 1985 (hard-rock ore).	Hard-rock Sn-Ta ore was downgraded to subeconomic since collapse of tin prices.
4,000; Sn in concentrates; 1968–85. 350; Sn in concentrates; 1961–68. 75; Sn in concentrates; 1939–61. 10; Sn in concentrates; 1920–39.	51,292; Sn in concentrates; 1974–85. 21,119; Sn in concentrates; 1967–74. 3,179; Sn in concentrates; Pre-1967. 8,776,622; 1.21 percent Sn; 1967–85.	18,560,000; R1E; 1.1 percent Sn; 1985. 11,300,000; R2E; 1.05 percent Sn; 1979.	Production and resource estimates are from Australia's Bureau of Mines and Resources.
<20; Sn; 1958–85.	6,062,000; ore grade not reported; 1871–1985. 62,000; Sn; 1871–1985.	1,329,000; R2S; 1.00 percent Sn; 1984 (dolomite ore). 3,402,000; R2S; 0.48 percent Sn; 1984 (porphyry ore).	Historically, metallurgical recovery was below 50 percent. Deposit was marginal prior to collapse in tin prices.
None	None	7,300,000; R1S; 0.70 percent Sn; 1982.	Lack of infrastructure and low metal prices are nongeological constraints.

TABLE 10.—*Selected production and mineral-resource information*

Site name	Year of discovery	Mining method	Year of first production	Materials of economic interest
Australia—Continued				
Taronga (New South Wales)	Pre-1886	S	None	Sn, Ag, Cu
Bolivia				
Bolivian central region deposits (Morococala district).	About 1840	U	Post-1840	Sn, Cu, W, Ag, Zn
Bolivian dredges	1920's	S (dredging)	1924	Sn
Bolivian northern region deposits (Morococala district).	Mid-1800's	U	1800's	Sn, Bi, Ag
Bolivian southern region deposits	About 1800	U	About 1800	Sn
Brazil				
Best Group (Rondônia and Pará States).	1978 (Ceriumbras).	S (gravel pump)	1980	Sn
Brascan Group (Rondônia tin province).	1800's	S (gravel pump, wash plants, dredges).	1800's	Sn
Brazilian prospects (Pará and Goiás States).	1973	S (gravel pump, open pit).	—	Sn

Annual production	Cumulative production	Resources	Comments
		Australia—Continued	
None	None	37,500,000; R1S; 0.153 percent Sn; 1982. 46,800,000; R1S; 0.145 percent Sn; 1983 (refinement of 1982 estimate). 19,700,000; R2S; 0.18 lpercent Sn, 0.06 percent Cu, 4.6 g/t Ag; 1980.	1982 feasibility study determined the low-grade deposit was subeconomic.
		Bolivia—Continued	
1,824,300; 0.55 percent Sn; 1982–84.	8,496; 60–80 percent Sn; 1982–84.	1,141,646; R1E; 0.55 percent Sn; 1984. 5,976,674; R1M; 0.55 percent Sn; 1982. 400,026,782; R1S; 0.08 percent Sn; 1982.	R1S represents waste material and tails. Once, 300 mining companies operated over 500 tin mines in this region.
6,923,000; 0.021 percent Sn; 1982–84. 16,323,000; 0.021 percent Sn (capacity).	2,830; 60–70 percent Sn; 1982–84.	57,709,131; r1E; 0.021 percent Sn; 1982.	Pay zone is about 27.5 m thick with 3.5 m cover. Production could more than double if market improved.
586,108; 0.78 percent Sn; 1982–84.	6,599; 60–80 percent Sn; 1982–84.	2,891,744; R1E; 0.78 percent Sn; 1982 (measured and indicated). 5,776,310; R2E; 0.78 percent Sn; 1982 (inferred). 13,723,853; R1S; 0.48 percent Sn; 1982 (waste and tailings).	Waste and tailings may be retreated to try to improve recovery by 10 percent.
1,824,300; 0.55 percent Sn; 1982–84.	—	1,141,646; R1E; 0.55 percent Sn; 1984. 5,976,674; R1M; 0.55 percent Sn; 1982. 400,026,782; R1S; 0.08 percent Sn; 1982 (waste piles, tailings, and low-grade material).	Outlook is bleak for Bolivian tin mines. Only government assistance/subsidies maintain production.
		Brazil—Continued	
299; 36 percent Sn; 1980–82. 871; contained Sn; 1984.	1,194; contained Sn; 1980–82, 1984.	6,261,000; R1E; 0.022 percent Sn; 1982. 18,125,000; R1M; 0.024 percent Sn; 1982.	R1E is demonstrated ore at Ceriumbras deposit. Magnetic separaters could be used to remove ilmenite and increase the concentrate grade.
3,333; 59.4 percent Sn; 1979–84.	18,500; 61 percent Sn; 1971–84.	34,403,700; R1E; 0.042 percent Sn; 1982. 39,429,500; R1M; 0.045 percent Sn; 1982. 500,000; R1E; 0.9 percent Sn; 1984 (Potosi Hill). 4,500; R1E; contained Sn; 1985 (Naturais deposit). 39,429,500; R1M; 0.045 percent Sn; 1982. 4,000; R2E; contained Sn; 1985 (Naturais deposit).	Nine paleovalleys are developed to 60-m depths.
—	—	551,700; R1E; 1.25 percent Sn; 1982 (Serra Branca). 13,000,000; R1E; 0.061 percent Sn; 1982 (Mocambo). 1,750; 50 percent Sn; 1987 (projected for Mocambo). 8,851,300; R2E; 0.98 percent Sn; 1982 (Serra Branca).	In 1984, annual production of 1,877 t at 65 percent Sn was projected for Serra Branca and Mocambo if and when the projects come on line.

TABLE 10.—*Selected production and mineral-resource information*

Site name	Year of discovery	Mining method	Year of first production	Materials of economic interest
		Brazil—Continued		
Brumadinho Group (Rondônia and Goiás States).	1970	S (dredging and open pit).	—	Sn
C–75 Garimpo (Rondônia State)	1987	S (gravel pump)	1987	Sn
Paranapanema group Pitinga (Mapuero tin district, Amazonas).	1980	S (onshore dredge)	1982	Sn, Nb, Ta, REE, zircon, xenotime.
Rhodia-Espeng (Pará State)	1978	S (gravel pump)	1983	Sn
		Burma		
Mawchi mine (Kayah Province)	—	U	—	Sn, W
Tenasserim Valley	—	S	—	Sn, W
		Canada		
East Kemptville (Nova Scotia)	1979	S	1985	Sn, Cu, Zn, Ag, topaz
Mount Pleasant (New Brunswick)	1954	U	1983 (W)	W, Sn
		China		
Dachang tin field (Guangxi Province).	1127	U	—	Sn, Zn, Pb, Sb, Ag, Cu, W, In.
Gejiu district (Yunnan Province)	At least 2,000 years ago.	U	At least 2,000 years ago alluvial deposits were worked.	Sn, Zn, Cu, Pb
		Indonesia		
Kelapa Kampit mine (Belitung)	1869	U (open stoping).	1977 (reopened)	Sn, Ta
P.T. Tambang Timah—Bangka (Bangka).	1700's	S (gravel pump and dredge).	1709	Sn, Ta

Annual production	Cumulative production	Resources	Comments
		Brazil—Continued	
1,767; about 63 percent Sn; 1980–84.	8,833; about 63 percent Sn; 1980–84.	60,034,200; R1E, 0.026 percent Sn; 1982 (Rondônia). 5,394,400; R1E; 0.84 percent Sn; 1982 (Goias). 105,609,300; R1M; 0.026 percent Sn; 1982.	Cachoeirha and Sao Domingo are producing deposits.
7–10,000; contained Sn; 1987.	7–10,000; contained Sn; 1987.	100,000; R1E; contained Sn; 1987	Mine life of about 5 years is expected as of 1987. Mining is inefficient with material being worked repeatedly.
11,770; contained Sn; 1985. 18,700; 63 percent Sn;	58,330; contained Sn; 1971–85.	500,000; R1E; contained Sn; 1987 (Unofficial estimates are several times larger. Calculations in this report are based on 1 million metric tons contained Sn R1E.)	Paranapanema has six operating alluvial-type properties. Three are in Rondonia, two are in Pará, and one in Pitinga in Amazonas. Collapse of world tin markets in 1985 allowed Pitinga to become the world's largest tin mine for the world's largest tin-mining company.
151.6; 65 percent Sn; 1983. 727.8; 65 percent Sn; 1984.	1,222,500; 0.04 percent Sn; 1979–82. 879.4; 65 percent Sn; 1983–84.	11,495,000; R1E; 0.034 percent Sn; 1982. 15,152,000; R1M; 0.034 percent Sn; 1982.	Demonstrated economic resources (R1E) are projected to be sufficient for capability production until 1989.
		Burma—Continued	
—	—	600,000; R1; 0.07 percent Sn, 0.52 percent W; 1983.	The Mawchi pluton is one of the smallest in the Burmese Sn-W granitoid belt.
—	—	—	Heinda mine was Burma's largest tin producer in 1978. It has since been modernized with a subsequent increase in production.
		Canada—Continued	
4,400; two grades of concentrates: 40 percent Sn and 65 percent Sn (capacity).	—	56,000,000; R1E; 0.165 percent Sn, 0.05 percent Cu, 0.09 percent Zn; 1984.	1,500 t of Cu concentrates and 2,400 t of Zn concentrates could also be produced annually.
None (Sn)	None (Sn)	5,900,000; R1M; 0.79 percent Sn; 1985.	Resources are total of six to eight separate zones. Feasibility study on tin production due in 1987–88.
		China—Continued	
1,000,000; recovery grades—0.6 percent Sn, 2 percent Zn, 0.5 percent Pb, 0.3 percent Sb; 1985.	—	50–100,000,000; R1E; 0.5–1.0 percent Sn; 1985. >20,000,000; R1S; 0.35 percent Sn; 1985 (tailings under study by the U.N.).	China has about 8 percent of world tin production and 15 percent of the world's tin resources (up to 2.5 million t of contained tin).
—	350,000; contained Sn; 1750–1960.	100,000,000; 1 percent Sn, 2–5 percent Cu, 0.5 percent Pb; 1985.	About one-half of the original ore has been mined.
		Indonesia—Continued	
35,000; 1.44 percent Sn; 1979–82.	2,000,000; 1.21 percent Sn; 1906–42. 140,000; 1.44 percent Sn; 1979–82.	1,390,000; R1E; 1.67 percent Sn; 1982.	Production capacity is 175,000 t ore per year. Market conditions have delayed plans to expand production by a factor of five.
54,900,000; 0.0348 percent Sn; 1978–82. 16,365; contained Sn; 1985.	274,542,000; 0.0348 percent Sn; 1978–82. 16,365; contained Sn; 1985.	2,259,000; R1E; 0.022 percent Sn; 1982.	In 1981, gravel pumps accounted for about 50 percent of tin production.

TABLE 10.—*Selected production and mineral-resource information*

Site name	Year of discovery	Mining method	Year of first production	Materials of economic interest
		Indonesia—Continued		
P.T. Tambang Timah—Belitung (Belitung).	1800's	S (gravel pump and dredge).	1800's	Sn, ilmenite, monazite
P.T. Koba Tin (Bangka)	1970's	S (gravel pump and dredge).	1974	Sn, ilmenite, monazite
		Japan		
Akenobe mine (Hyōgo Prefecture, Honshū Island).	1908	U	1936	Sn, Cu, Zn, Au, Ag, W
Suzuyama mine (Kyūshū Island)	1655	U	1840's	Sn
		Malaysia		
Malaysian dredges (Southeast Asian Tin Belt).	—	S (dredge)	1900's	Sn
Malaysian gravel pump mines (Southeast Asian Tin Belt).	1900's	S (gravel pumps)	1900's	Sn
Sungei Lembing (Southeast Asian Tin Belt).	1700's	U	—	Sn
		Namibia		
Uis tin mine (Southern Damaraland)	1911	S	1924	Sn, Nb, Ta
		Nigeria		
Jos Plateau deposits. (Bauchi, Benue, Kano, and Zaria States).	1902	S	1905	Sn, Nb, W
		Peru		
San Rafael mine (Melgar Province)	1965	U	1970	Sn, Cu

from ISMI records for tin deposits and districts—Continued

Annual production	Cumulative production	Resources	Comments
		Indonesia—Continued	
52,947,000; 0.0104 percent Sn; 1978–81.	270,000,000; 0.0104 percent Sn; 1978–82.	1,764,000; R1E; 0.012 percent Sn; 1982. 21,616,656; R1M; 0.0132 percent Sn: 1981.	—
6,482; Sn in concentrates; 1981–82. 4,053; Sn in concentrates; 1985.	31,910; contained Sn; 1980–85.	23,400; R1E; contained Sn; 1982. 26,300; R1M; contained Sn; 1982.	Dredges account for the majority of Indonesian production. In 1980, P. T. Koba was the largest foreign mining company in Indonesia.
		Japan—Continued	
425; contained Sn; 1980–81.	849; contained Sn; 1980–81. 12,438,000; 0.37 percent Sn, 1.09 percent Cu, 2.0 percent Zn; 1946–80.	40,000; R1E; contained Sn; 1980. 200,000; R1E; contained Zn; 1980. 150,000; R1E; contained Cu; 1980.	Akenobe supplied 50 percent of total domestic production for many years.
8,000; 1.00 percent Sn; 1982–84.	37,600; 1.00 percent Sn; 1980–84.	168,000; R1E; 1.0 percent Sn; 1982–84. 280,000; R2E; 1.25 percent Sn; 1982.	In 1960, total identified economic resources for five Japanese tin mines were estimated to be 2.7 million metric tons at 1.2 tin.
		Malaysia—Continued	
12,870; >98 percent Sn; 1983–84. 17,430; >98 percent Sn; 1980–82.	298,900; >98 percent Sn; 1970–84. 96,200; >98 percent Sn; 1966–69.	300,000; R1E; >98 percent Sn; 1985. 209,000; r1E; contained Sn; 1985. 12,200; R2S; >98 percent Sn; 1985.	During 1970–84, about 32 percent of Malaysia's tin was produced by dredges. Average dredge grade: 1971–73, 0.18 percent Sn; 1977–78, 0.155 percent Sn.
21,600; >98 percent Sn; 1983–84. 31,900, >98 percent Sn; 1980–82.	504,400; >98 percent Sn; 1970–84. 162,467; >98 percent Sn; 1966–69.	900,000; R1E; >98 percent Sn; 1985. 800; R1S; >98 percent Sn; 1985. 9,100; R2E; >98 percent Sn; 1985.	Between 1970–84, gravel pumps accounted for about 54 percent of Malaysian tin production. Average grade of Malaysian gravel pump ore: 1971–73, 0.30 percent Sn; 1977–78, 0.18 percent Sn.
198,344; 0.71 percent Sn; 1980. 210,368; 0.71 percent Sn; 1967–79.	287,500; >3.0 percent Sn; 1887–1905. 2,933,127; 0.71 percent Sn; 1967–80.	1,073,997; R1E; 0.71 percent Sn; 1982.	Mine was indefinitely closed in 1987 due to high operating costs and poor reserves.
		Namibia—Continued	
1,180; 65 percent Sn; 1966–87.	27,391.24; 60 percent Sn; 1924–84. 4,717; 66.77 percent; Sn; 1980–84.	3,000,000; R1E; 0.75 percent Sn; 1977. 13,700,000; R1E; 0.15 percent Sn; 1977.	Cumulative production excludes 1930–33 and 1946–52. If mining took place in those years, it was not reported.
		Nigeria—Continued	
9,261.7; contained Sn; 1946–55 (total Nigerian production). 8,487.2; contained Sn; 1956–65 (total Nigerian production). 8,883.2; contained Sn; 1966–71 (total Nigerian production).	92,617; contained Sn; 1946–55 (total Nigerian production). 84,872; contained Sn; 1956–65 (total Nigerian production). 53,299; contained Sn; 1966–71 (total Nigerian production).	110,829; R1E; contained Sn; 1969 (total Nigerian R1E).	As of 1976, 98 percent of Nigeria's tin production came from Jos Plateau. Columbite is an important byproduct.
		Peru—Continued	
1,500; contained Sn; 1981. 900; contained Sn; 1980	>10,000; 42.2 percent Sn; 1970–82.	223,000; R1E; 10.1 percent Sn, 0.28 percent Cu; 1980.	Began as a copper mine and began to yield substantial cassiterite in the early 1970's. Resources are for two tin-rich pockets.

Table 10.—*Selected production and mineral-resource information*

Site name	Year of discovery	Mining method	Year of first production	Materials of economic interest
		Portugal		
Neves-Corvo (Baixo Alentejo Province).	1977	U	1990 (planned)	Cu, Sn, Ag, Zn, Pb, Fe
		South Africa		
Kuils River tin (Cape Province)	1905	S, U	1905	Sn, W
Rooiberg tin mines (Transvaal)	1905	U	1905	Sn, Cu
Van Rooi's Vley (Cape Province)	1943	S, U	1943	W, Sn
Union tin mine (Transvaal)	1908	U	1910	Sn
Zaaiplaats tin mine (Transvaal)	1906	S, U	1906	Sn, W, sulfides
		Soviet Union		
Soviet Union southern mining regions (Chita, Khabarovsk).	—	S	—	Sn
Soviet Union northern mining regions (Magadan Oblast and Yakut, ASSR).	—	U	—	Sn
		Thailand		
Thai dredging operations (Southeast Asian Tin Belt).	—	S (dredging)	—	Sn, Ta, W
Thai gravel pump operations (Southeast Asian Tin Belt).	1800's	S (gravel pump)	—	Sn, Ta, W
Thai hard-rock and open-cast operations (Southeast Asian Tin Belt).	1800's	S, U	—	Sn, W, Ta
		United Kingdom		
Geevor mine (St. Just mining district).	Pre-1500	U	Pre-1500	Sn, Cu, As

from ISMI records for tin deposits and districts—Continued

Annual production	Cumulative production	Resources	Comments
		Portugal—Continued	
5,000; tin-in-concentrate; 1990 (planned).	None	2,800,000; R1E; 2.6 percent Sn; 1989.	Metallurgical problems (which are being researched) preclude more resources from being economic. Deposit also contains 35 million metric tons with 8.4 percent Cu.
		South Africa—Continued	
258.5; 70 percent Sn; 1913–19.	800; 70–75 percent Sn; 1905–56.	705,000; R1E; 2.44 percent Sn; 1973. 2,820,000; R1S; 2.4 percent Sn; 1981.	Highest production was in 1919.
528,000; 0.5 percent Sn; 1982–86.	11,200,000; 0.62 percent Sn; 1905–86.	—	As ore grade decreased, tonnage increased to keep production stable.
30; 65 percent Sn; (1 year).	150; 65 percent Sn; (5 years).	2,500,000; R1E; 0.21 percent Sn, 0.38 percent WO_3; 1984.	Wolframite and scheelite in roughly equal amounts; cassiterite slightly subordinate to tungsten.
54,000; ore; 1986	10,000; about 43 percent Sn; 1953–83. 15,627; 43.1 percent Sn; 24 years of production.	—	Concentrates from low-grade ore range from 43.1 to 50 percent Sn.
216; contained Sn; 1983–86 (recovery grade is 0.241 percent Sn).	31,660; Sn concentrates; 1908–83 (from 3,324,624 t of ore).	1,000,000; R1E; 0.25 percent SnO_2; 1987. 4–6,000,000; r1E; 0.15 percent SnO_2; 1986 (tied up with quartz in tailings).	In 1983, the concentrate-dressing section was rebuilt, increasing annual production.
		Soviet Union—Continued	
22,000; contained Sn; 1981–85 (production for the entire Soviet Union).	111,000; contained Sn; 1981–85 (production for the entire Soviet Union).	150,000; R1E; contained Sn; 1989 (one-half of national estimate).	As of 1980, about 70 percent of Soviet tin is mined from lode deposits, although offshore exploration and dredging are planned.
—	—	150,000; R1E; contained Sn; 1989 (one-half of national estimate).	Tin is one of the few metals for which the Soviet Union is significantly dependent on imports. An additional rail line has made Siberia more accessible. About one-third of the tin in the ore is lost.
		Thailand—Continued	
134,544,400; 0.024 percent Sn; 1981–82.	269,088,800; 0.024 percent Sn; 1981–82.	2,583,743,000; R1E; 0.024 percent Sn; 1982.	Most Thai dredging operations stockpile waste containing heavy minerals that may someday be salable.
22,823; 76 percent Sn; 1982–84. 210; 72 percent WO_3; 1982–84.	69,286; contained Sn; 1981–84.	1,630,500,000; R1E; 0.015 percent Sn; 1984.	Production includes dredge and open-cast production for some deposits.
2,947,000; 0.15 percent Sn; 1981–82. 0.7085; Ag; 1984 (Eurothai mine). 7; W, 1983 (Sichon mine).	—	54,220,000; R1E; 0.136 percent Sn; 1982. 12.05; R1E; Ag; 1984 (Eurothai mine). 200; R1E; W; 1984 (Sichon mine).	Production probably decreased by 30–40 percent after the tin crisis of Oct. 1985. High costs of these operations will keep them operating at reduced levels until tin prices rise.
		United Kingdom—Continued	
823; contained Sn; 1982–85 (from ore of 0.71 percent Sn). 140; contained Sn; 1982–85 (from mine dump with 0.25 percent Sn).	3,795; contained Sn; 1982–85.	446,000; R1S; 0.75 percent Sn; 1986 (mine). 250,000; R1S; 0.25 percent Sn; 1986 (dump reworking).	Mine ceased to be profitable Oct. 1985. It is an old, deep mine with restricted shaft access.

TABLE 10.—*Selected production and mineral-resource information*

Site name	Year of discovery	Mining method	Year of first production	Materials of economic interest
		United Kingdom—Continued		
South Crofty mine (Camborne, Redruth mining district).	Pre-1592	U	1710	Sn, W, U
Wheal Jane (St. Day mining district)	About 1740	U	About 1740	Sn, Zn, Cu
		United States		
Lost River district (Alaska)	1903	U	1904	Sn, W, Be, F
		Zaire		
Kivu mines (Maniema-Kivu area)	1936	S	1938	Sn, Nb, W, monazite, Au, Ta.
		Zimbabwe		
Kamativi tin mines (Wankie)	1936	S, U	About 1940	Sn, Ta

Annual production	Cumulative production	Resources	Comments
		United Kingdom—Continued	
1,645; contained Sn; 1983–85 (from ore of 0.83 percent Sn).	9,368; contained Sn; 1983–85 (from ore of 0.86 percent Sn).	3,850,000; R1M; 1.55 percent Sn at 1.0 percent cutoff; 1987.	Reserves are best in United Kingdom tin mining.
1,830; contained Sn; 1983–85 (from ore of 0.84 percent Sn). 7,027; contained Zn; 1983–85 (from ore of 2.8 percent Zn). 635; contained Cu; 1983–85 (from ore of 0.26 percent Cu).	5,505; contained Sn; 1983–85 (from ore of 0.84 percent Sn).	2,380,000; R1M; 0.89 percent Sn, 2.83 percent Zn, 0.28 percent Cu; 1987.	The mine is modern and well equipped, but mine layout and plant limit production capacity.
		United States—Continued	
46,000; 1.0–2.0 percent Sn; 1953, 1955.	315.4; contained Sn; 1904–55 (lode deposit). 83.7; contained Sn; 1904–55 (placers).	2,400; R1E; contained Sn; 1963 (ore grade 1.3 percent Sn).	Only the cassiterite and Ida Bell dikes are of importance for tin or tungsten mining. Mine operated intermittently to 1955.
		Zaire—Continued	
3,572; 76 percent Sn, 0.478 Au; 1984–85. 2,582; 76 percent Sn; 1983.	12,314; 76 percent Sn, Au produced in small quantities; 1982–85. 5,793, Sn concentrates; 1980–81. 3,716; 64 percent cassiterite; 10 percent columbite, 10 percent wolframite, 16 percent monazite; 1969–72.	265,000; R1E; contained Sn; 1986 (Manono deposit). 510,000; R1E; contained Sn; about 1986 (total resources for Zaire).	Zaire is a high-cost producer because of high infrastructure costs—especially transportation costs—and because the small size of alluvial placers does not allow large shovels and more economical mining techniques to be used.
		Zimbabwe—Continued	
1,239; sales of Sn metal; 1983. 1,173; contained Sn; 1982. 1,157; contained Sn; 1981. 934; contained Sn; 1980	4,503; contained Sn; 1980–83. 4,414; 66.8 percent Sn in concentrates from ore of 0.32 percent Sn; 1956–61. 3,000; about 63–69 percent Sn, 2–3 percent Ta_2O_5-Nb_2O_5; 1940–51.	100,000,000; R2E; 0.114 Sn, 0.603 LiO_2; 1962 (maximum inferred tonnage of a single pegmatite).	Production is 70 percent from the surface, 30 percent from underground. In 1981, a new open pit was built to provide 10,000 t per day of 0.192-percent Sn ore.

REFERENCES CITED

American Metal Market, 1987, Metal statistics, 80th annual ed.: New York, Fairchild Publications, 290 p.

Anderson, J. A., 1986, The discovery of the Zeehan cassiterite deposits—An example of metal and deposit multiplicity from a historical mining district: Aberfoyle Limited, unpub. draft, 8 p.

Angermeier, H. O., Krauss, U., Krusona, M., and Schmidt, H., 1974, Rohstoffwirtschaftliche Länderberichte, v. III, Zaire: Hannover, Germany, Federal Republic, Bundesanstalt für Bodenforschung, 120 p.

Baldwin, W. L., 1983, The world tin market—Political pricing and economic competition: Durham, North Carolina, Duke University Press, 273 p.

Barry, B. T. K., and Thwaites, C. J., 1983, Tin and its alloys and compounds: West Sussex, England, Ellis Horwood Ltd., 268 p.

Bellasis, J. W. M., and van der Heyde, C., 1962, Operations at Kamativi Tin Mines Ltd., Southern Rhodesia: [Zimbabwe] Chamber of Mines Journal, v. 4, no. 9 (Sept.), p. 36–41.

Bettencourt, J. S., Damasceno, E. C., Fontanelli, W. S., Franco, J. R., and Pereira, N. M., 1981, Brazilian tin deposits and potential, *in* Fifth World Conference on Tin, 19–23 Oct., 1981, meeting, Kuala Lumpur: London, International Tin Council, paper 3 (ii), 69 p.

Bleiwas, D. I., Sabin, A. E., and Peterson, G. R., 1986, Tin availability—Market economy countries; A Minerals Availability Program appraisal: U.S. Bureau of Mines Information Circular 9086, 50 p.

Blockley, J. G., 1980, The tin deposits of Western Australia—With special reference to the associated granites: Geological Survey of Western Australia Mineral Resources Bulletin 12, 184 p.

British Geological Survey, 1985, World mineral statistics 1979–83: London, Her Majesty's Stationery Office, 275 p.

Brown, W. M., Kwak, T. A. P., and Askins, P. W., 1984, Geology and geochemistry of a F-Sn-W skarn system—The hole 16 deposit, Mount Garnet, North Queensland, Australia: Australian Journal of Earth Sciences, v. 31, no. 3, p. 317–340.

Carlin, J. F., Jr., 1987, Tin, *in* U.S. Bureau of Mines, Minerals yearbook 1985, v. 1, Metals and minerals: Washington, D.C., U.S. Government Printing Office, p. 963–974.

———1989, Tin, *in* U.S. Bureau of Mines, Mineral commodity summaries 1989: Washington, D.C., U.S. Government Printing Office, p. 170–171.

Carvalho, D., 1988, Case history of the Neves-Corvo massive sulphide deposit, Portugal: Geological Society of America Abstracts with Programs, v. 20, p. A32.

Clark, A. H., Palma, V. V., Archibald, D. A., Farrar, Edward, Arenas, M. J., and Robertson, R. C. R., 1983, Occurrence and age of tin mineralization in the Cordillera Oriental, southern Peru: Economic Geology, v. 78, no. 3, p. 514–520.

Clarke, G. W., Paterson, R. G., and Taylor, R. G., 1985, The nature and origin of brecciation and mineralization at the White Crystal ore deposit, Ardlethan tin mine, New South Wales: Australian Journal of Earth Sciences, v. 32, no. 4, p. 343–348.

Collins, P. L. F., 1986, Tin and tungsten deposits in Western Tasmania: IGCP Project 220, Correlation and resource evaluation of tin/tungsten granites in SE Asia and the Western Pacific region, Joint meeting of Working Group, 2 and 4, 30 June–2 July, Canberra, Australia.

Davis, P. E., 1985, Tin and tin alloy coatings—Yesterday, today, and tomorrow: Plating and Surface Finishing, v. 72, no. 12, p. 26–29.

Dines, H. G., 1956, The metalliferous mining region of South-West England, v. 1 and 2, Memoirs of the Geological Survey of Great Britain: Her Majesty's Stationery Office, 795 p.

Evans, C., 1988, Tin chemicals for industry: Tin International, v. 61, no. 10, p. 14–17.

Fox, D. J., 1971, Tin mining in Bolivia: Mining Magazine, v. 124, no. 1, p. 11–23.

Govett, M. H., and Robinson, H. A., eds., 1980, The world tin industry—Supply and demand: Sydney, Australian Mineral Economics Proprietary Ltd., 278 p.

Hill, R. S., and Brunker, E. G., 1981, The tin occurrences of the south-western Cape Province: Geological Survey of South Africa Open-File Report 1981–0136, 49 p.

Hosking, K.F.G., 1974, The search for deposits from which tin can be profitably recovered now and in the foreseeable future: Fourth World Tin Congress, Kuala Lumpur, International Tin Council I, p. 21–84.

Hutchinson, R. W., 1981, Lode tin deposits of exhalative origin, *in* Hassan, A.H.H., and van Wees, Hubertus, eds., Complex tin ores and related problems: Setrad Center Technical Publications, no. 2, Ipoh, Malaysia, p. 81–97.

Kashida, A., Lobato, L., Lindenmeyer, Z., and Fyfe, W. S., 1990, Introduction—Brazil, the sleeping resource giant: Economic Geology, v. 85, no. 5, p. 899–903.

Khin, Zaw, and Thet, D. K. M., 1983, A note on a fluid inclusion study of tin-tungsten mineralization at Mawchi mine, Kayah State, Burma: Economic Geology, v. 78, no. 3, p. 530–534.

Kooiman, G. J. A., McLeod, M. J., and Sinclair, W. D., 1986, Porphyry tungsten molybdenum orebodies, polymetallic veins and replacement bodies, and tin-bearing greisen zones in the Fire Tower Zone, Mount Pleasant, New Brunswick: Economic Geology, v. 81, no. 6, p. 1356–1373.

Krosch, N. J., 1985, Tin and tungsten potential in Queensland: Queensland Government Mining Journal, January 1985, p. 16–25.

Kwak, T. A. P., 1987, W-Sn skarn deposits and related metamorphic skarns and granitoids: New York, Elsevier, Developments in Economic Geology, v. 24, 451 p.

Longe, R. V., and others, 1978, Computer-based files on mineral deposits—Guidelines and recommended standards for data content [prepared by the Mineral Deposits Working Committee, National Advisory Committee on Research in the Geological Sciences]: Geological Survey of Canada Paper 78–26, 72 p.

MacLeod, W. N., Turner, D. C., and Wright, E. P., 1971, The geology of the Jos Plateau, v. 1, The geology: Geological Survey of Nigeria Bulletin, no. 32, 118 p.

Mareno, Ann-Marie, 1986, The tin industry in Brazil, *in* Tin International, A special issue, The market for tin: Proceedings of the International Tin Symposium (London, Dec. 17, 1985), p. 72–78.

Mayo, Elizabeth, 1988, Tin—An uneventful year in '87: Engineering and Mining Journal, v. 189, no. 4, p. 53–56.

Menzie, W. D., and Reed, B. L., 1986a, Grade and tonnage model of Sn greisen deposits, *in* Cox, D. P., and Singer, D. A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 71–72.

———1986b, Grade and tonnage model of replacement Sn, *in* Cox, D. P., and Singer, D. A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 62–63.

Metallgesellschaft Aktiengesellschaft, 1961, Metal statistics 1951–1961: Frankfurt am Main (Germany, Federal Republic), Metallgesellschaft A.G., 48th ed., 255 p.

———1984, Metallstatistik 1973–83: Frankfurt am Main (Germany, Federal Republic), Metallgesellschaft A.G., 71st ed., 424 p.

———1986, Metallstatistik 1975–85: Frankfurt am Main (Germany, Federal Republic), Metallgesellschaft A.G., 73d ed., 448 p.

———1988, Metallstatistik 1977–87: Frankfurt am Main (Germany, Federal Republic), Metallgesellschaft A.G., 75th ed., 472 p.

Mining Journal, 1987, Tin—A word of caution: Mining Journal, v. 308, no. 7899, p. 17–18.

———1988a, Tin pact fears: Mining Journal, v. 311, no. 7996, p. 414.

———1988b, Neves-Corvo expansion: Mining Journal, v. 311, no. 7999, p. 477.

———1989a, Brazil's ascendancy: Mining Journal, v. 312, no. 8003, p. 52.

———1989b, ATPC move fails to subdue tin mining: Mining Journal, v. 312, no. 8015, p. 294.

Morland, R., 1986, Renison Bell tin mine—Technical review: Renison Associated Tin Mines, unpub. report, 22 p.

Moyle, J. E., 1984, Development and construction begins in East Kemptville, North America's only primary tin mine: Mining Engineering, v. 36, no. 4, p. 335–336.

Nutalaya, Prinya, Campbell, K. V., MacDonald, A. S., Aranyakanon, Payome, and Suthakorn, Phairat, 1979, Review of the geology of Thai tin fields, *in* Yeap, C. H., ed., Geology of tin deposits: Geological Survey of Malaysia Bulletin, no. 11, p. 137–159.

Offenberg, A. C., 1982, Geology, mineralization and exploration of the Taronga tin prospect Emmaville, New South Wales: Sydney Mineral Exploration Group seminar.

Omer-Cooper, W. R. B., Hewitt, W. V., and van Wees, H., 1974, Exploration for cassiterite-magnetite-sulphide veins on Belitung, Indonesia, *in* Allen, H. W., chairman, Fourth world conference on tin, Kuala Lumpur, 1974, v. II: United Kingdom, International Tin Council, p. 96–119.

Patterson, D. J., Ohmoto, H., and Solomon, M., 1981, Geologic setting and genesis of cassiterite-sulphide mineralization at Renison Bell, western Tasmania: Economic Geology, v. 76, no. 2, p. 393–438.

Plimer, I. R., 1984, Malayite and tin bearing silicates from a skarn at Doradilla via Bourke, New South Wales: Australian Journal of Earth Sciences, v. 31, no. 1, p. 147–153.

Premoli, Camillo, 1986, China's tin potential—With special reference to Dachang tin field: Mining Magazine, v. 154, no. 1, p. 28–40.

Prijono, I. A., 1986, Indonesia, *in* Mining Journal Ltd., Mining Annual Review 1986: Mining Journal Ltd., p. 381–383.

Pringle, I. C., 1986, The Union tin mine, Naboomspruit district, *in* Anhaeusser, C. R., and Maske, S., eds., Mineral deposits of southern Africa: Geological Society of South Africa, p. 1301–1305.

Reed, B. L., Duffield, Wendell, Ludington, S. D., Maxwell, C. H., and Richter, D. A., 1986, Descriptive model of rhyolite-hosted Sn, *in* Cox, D. P., and Singer, D. A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 168.

Richards, T. E., 1986, Geological characteristics of rare-metal pegmatites of the Uis type in the Damara orogen, South West Africa/Namibia, *in* Anhaeusser, C. R., and Maske, S., eds., Mineral deposits of southern Africa: Geological Society of South Africa, p. 1845–1862.

Richardson, J. M. G., Spooner, E. T. C., and McAuslan, D. A., 1982, The East Kemptville tin deposit, Nova Scotia—An example of a large tonnage, low grade, greisen-hosted deposit in the endocontact zone of a granite batholith: Geological Survey of Canada, Current Research, pt. B, paper 82–1B, p. 27–32.

Rijks, H. R. P., and Van de Veen, A. H., 1972, The geology of the tin-bearing pegmatites in the eastern part of the Kamativi district, Rhodesia [Zimbabwe]: Mineralium Deposita, v. 7, no. 4, p. 383–395.

Robertson, William, 1982, Tin—Its production and marketing: London, Croom Helm, 212 p.

Ross, Field, 1941, Pirquitas mine—A tin silver property in Argentina: Engineering and Mining Journal, v. 42, no. 8, p. 153–154.

Rozendal, A., Toros, M. S., and Anderson, J. R., 1986, The Rooiberg tin deposits, west-central Transvaal, *in* Anhaeusser, C. R., and Maske, S., eds., Mineral deposits of southern Africa: Geological Society of South Africa, p. 1307–1327.

Sainsbury, C. L., 1964, Association of beryllium with tin deposits rich in fluorite: Economic Geology, v. 59, no. 5. p. 920–926.
———1969, Geology and ore deposits of the central York Mountains, Seward Peninsula, Alaska: U.S. Geological Survey Bulletin 1287, 101 p.
———1970, Tin and beryllium deposits of the central York Mountains, western Seward Peninsula, Alaska, *in* Ridge, J. D., Ore deposits in the United States 1933/1967: New York, American Institute of Mining, Metallurgical, and Petroleum Engineers, Graton-Sales Volume, p. 1555–1572.
Sainsbury, C. L., and Reed, B. L., 1973, Tin, *in* Brobst, D. A., and Pratt, W. P., eds., United States mineral resources: U.S. Geological Survey Professional Paper 820, p. 637–651.
Saito, M., Hashimoto, K., Sawata, H., and Shimazaki, Y., 1960, Geology and mineral resources of Japan (2d ed.): Geological Survey of Japan, Hisamoto-cho, 314 p.
Sato, Noritaka, and Akiyama, Yoshio, 1980, Structural control of the Akenobe tin-polymetallic deposits, southwest Japan: Mining Geology Special Issue (Tokyo), no. 8, p. 175–188.
Schanz, J. J., Jr., 1980, The United Nations' endeavor to standardize mineral resource classification: Natural Resources Forum, v. 4., no. 3., p. 307–313.
Scherer, F. M., 1970, Industrial market structure and economic performance: Chicago, Rand McNally College Publishing Co., 576 p.
Sillitoe, R. H., Halls, C., and Grant, J. N., 1975, Porphyry tin deposits in Bolivia: Economic Geology, v. 70, no. 5, p. 913–927.
Singer, D. A., and Mosier, D. L., 1986, Grade and tonnage model of rhyolite-hosted Sn, *in* Cox, D. P., and Singer, D. A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 169–171.
Smirnov, V. I., ed., 1977, Ore deposits of the USSR, v. III: London, Pitman Publishing Co., 492 p.
Taylor, R. G., 1979, Geology of tin deposits, *in* Developments in economic geology, no. 11: New York, Elsevier Scientific Publishing Company, 543 p.
Thorman, C. H., and Drew, L. J., 1988, A report on site visits to some of the largest tin deposits in Brazil: U.S. Geological Survey Open-File Report 88–0594, 19 p.
Tin International, 1986, Paranapanema 25 years of reserves: v. 59, no. 8, p. 270.
———1989a, New Brazilian supermine?: v. 62, no. 1 (Jan.), p. 6.
———1989b, GSA tin sales to increase in 1990/91: v. 62, no. 6, p. 2.
United Nations Economic and Social Council, 1979, The international classification of mineral resources—Report of the Group of Experts on Definitions and Terminology for Mineral Resources: United Nations document E/C.7/104, 28 p. including annexes.
U.S. Bureau of Mines, 1940–88, Tin, *in* U.S. Bureau of Mines, Minerals yearbook, v. I, Metals and minerals: Washington, D.C., U.S. Government Printing Office, 118 p.
U.S. Bureau of Mines and U.S. Department of Commerce, Basic Industries Sector, 1986, Domestic consumption trends 1972–82, and forecasts to 1993 for twelve major metals: U.S. Bureau of Mines Open-File Report 27–86, 158 p.
U.S. Geological Survey, 1921, World atlas of commercial geology—pt. I, Distribution of mineral production: Washington, D.C. [144 p.].
Velasco, Pablo, 1988, The mineral industry of Bolivia, *in* U.S. Bureau of Mines, Minerals yearbook 1986, v. III, Area reports—International: Washington, D.C., U.S. Government Printing Office, p. 119–128.
von Backström, J. W., 1950, Notes on a tungsten-tin deposit near Upington, Gordonia district: Geological Society of South Africa Transactions, v. 53, p. 35–51.
World Bank, 1986, World development report 1986: New York, Oxford University Press, 256 p.
Zaaiplaats Tin Mining Co., 1983, 75th anniversary report, Zaaiplaats Tin Mining Co. 1908–1983: Zaaiplaats Tin Mining Co.

ADDITIONAL REFERENCES ON TIN RESOURCES

Beer, K. E., and Ball, T. K., 1986, Tin and tungsten in pelitic rocks from S.W. England and their behavior in contact zones of granites and in mineralized areas: Proceedings of the Ussher Society, v. 6, p. 330–337.
Carlin, J. F., Jr., 1985, Tin: U.S. Bureau of Mines Bulletin 675, Mineral facts and problems, 1985 edition, p. 847–858.
———1987, Tin, *in* U.S. Bureau of Mines, Mineral commodity summaries 1987: Washington, D.C., U.S. Government Printing Office, p. 168–169.
Crocker, I. T., Coetzee, G. L., and Mehliss, M., 1976, Tin, *in* Coetzee, C. B., ed., Mineral resources of the Republic of South Africa (5th ed.): Geological Survey of South Africa Handbook 7, p. 213–219.
Sainsbury, C. L., 1969, Tin resources of the world: U.S. Geological Survey Bulletin 1301, 55 p.
Yeap, C. H., ed., 1979, Geology of tin deposits—A collection of papers presented at the International Symposium of 'Geology of Tin Deposits,' 23–25 March 1978, Kuala Lumpur: Geological Society of Malaysia Bulletin, no. 11, 392 p.

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