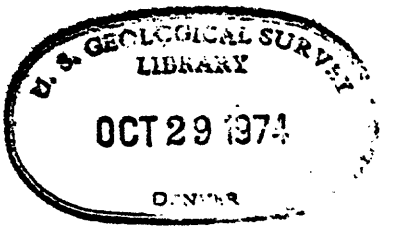
TIN RESOURCES OF BRAZIL

by

Max G. White



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ABSTRACT

Annual tin production in Brazil, most of it from cassiterite placer deposits in Rondônia Territory, amounts to about 4,000 metric tons (4,400 short tons) of concentrate containing 66 percent tin, much of which is consumed by Brazilian industry.

Reserves of cassiterite concentrate in the placers of Rondônia district are estimated at about 160,000 tons (176,000 short tons) containing 66 percent tin. Extensive undiscovered resources of cassiterite possibly exist in southern Rondônia Territory and to the east of the Territory in northern Mato Grosso, southern Amazonas, and southern Pará. Numerous occurrences have been reported in these regions and as far to the east as the headwaters of the Tapajós and the Xingú Rivers.

Minor deposits or occurrences of cassiterite (or lode deposits about which there is only minimal information available) are located in Pará, Amapá, Paraíba, Rio Grande do Norte, Ceará, Bahia, Minas Gerais, Goiás, São Paulo, and Rio Grande do Sul.

All the lode tin deposits are dated or enclosed in rocks that date as Precambrain B (900 to 1,300 m.y.).

INTRODUCTION

Most of the tin resources of Brazil are in cassiterite placers of the Territory of Rondônia in western Brazil. On the basis of present knowledge, the Departamento Nacional da Produção Mineral (D.N.P.M.), the official mining agency of the Ministry of Mines and Energy of the Brazilian government, estimates the reserves of cassiterite concentrate within the northern portion of the Territory, where exploratory work has been done, as 160,000 metric tons (176,000 short tons) containing 66 percent tin.

Rondônia is a remote region of Brazil that until recently was accessible only by air or via the Madeira River to the head of navigation at Pôrto Velho. In the past few years, the accessibility of the Territory has been improved by construction of a highway that connects Porto Velho to the industrial centers of south Brazil and of a road from Porto Velho to the south bank of the Amazon River across from Manáus.

The deposits were discovered in the early 1950's and their development has been slow. They are located in the thick tropical rain-forest that covers most of the Territory, making exploration-development work time consuming and expensive, with the result that extraction of the cassiterite fell to the prospector or "garimpeiro" rather than to organized mining operations. Along with the construction of roads that made Rôndonia accessible to trucking, and in order to stimulate more efficient extraction methods, the Brazilian government in 1971

abolished the "garimpo" regimen and issued mining licenses only to companies in the private sector prepared to undertake mechanized mining of the deposits. A tin smelter was installed at Manaus to process the cassiterite concentrates.

The undiscovered tin resources of western Brazil may be substantial, taking into consideration similar geologic environments to that in which the deposits of northern Rôndonia are found, such as in southern Rondônia, and numerous reported cassiterite placer occurrences in the region — such as on the Madeirinha River in northern Mato Grosso and in the upper Aripuaña River Valley in southern Amazonas. Unconfirmed occurrences are reported to the east of the Rondônia tin district in the headwaters of the Tapajós and the Xingú Rivers. Minerals exploration-reconnaissance of the region is slow and costly and can only proceed as viable penetration of the area is made. In any case, in 1971 the DNPM received 465 applications for exploration license for cassiterite in the Amazon region.

Acknowledgement

The writer expresses his appreciation to Emiliano Cornelio de Souza, chief of the Rondônia tin investigations project of the Companhia de Pesquisa de Recursos Minerais, for reviewing this report and making suggestions for its improvement.

TIN RESOURCES

The cassiterite deposits and occurrences of Brazil are found in the Territory of Rondônia and adjacent areas in the States of Amazonas and Mato Grosso; in the States of Pará, Goiás, Bahia, Minas Gerais, São Paulo and Rio Grande do Sul; and, in the northeastern States of Rio Grande do Norte, Paraíba, and Ceará. Minor placers are located in the Territory of Amapá and unconfirmed occurrences are reported on tributaries of the Amazon River in northern Mato Grosso and southern Amazonas and Pará.

Production and development

Tin production in Brazil has gradually increased since 1960, largely because of the development of the cassiterite placers of Rondônia Territory, whence comes the bulk of Brazilian production. Much of the production is consumed by Brazilian industry. Official published figures (DNPM, 1972-a) show the following tonnages by year:

	Metric tons of concentrate with 66 percent tin (1 metric ton equals 1.1 short tons).
1960	241
1961	711
1962	1,000
1963	1,603
1964	1,116
1965	2,833
1966	2,632
1967	2,675
1968	3,298
1969	3,713
1970	5,100
1971	3,453
1972	4,327

Cassiterite exploration and development activities are reflective of the general surge of interest in minerals and mining in Brazil, stimulated by the Brazilian Government. The Departamento Nacional da Producão Mineral (DNPM), the mineral licensing authority of the Government of Brazil, reports (DNPM 1972-a) that in calendar year 1971 a total of 528 applications for exploration licenses for cassiterite were filed--88 percent for the Amazon basin. In the same year DNPM issued only 189 licenses -- 95 percent in the Amazon: in Rondônia, Mato Grosso, and Amazonas. The lesser number of licenses issued than applied for does not necessarily reflect the extent of license refusal as it does delays in processing documents. The magnitude of exploration areas for cassiterite is indicated by the fact that according to the Brazilian mining code, as amended (DNPM, 1970, p. 86), tin comes under the category of a commodity for which an area of 1,000 hectares (2,470 acres) of area per exploration license is allowed. If however, the deposit is in what is considered a remote region of difficult access, such as the Amazon valley, up to 10,000 hectares (24,700 acres) per license is allowed.

Officially 81 tin mines are registered in Brazil, many of which are not currently in operation. The deposits mined are largely placer operations, but some are lode, and production comes from Precambrian rocks of the Brazilian shield. Some of the mines produce cassiterite as a co-product of other minerals, including wolframite and columbite-tantalite. The distribution of licensed mines in Brazil by political

unit of the country is as follows:

	Number of Mines
Rondônia	33
Amazonas	7
Amapá	2
Ceará	1
Paraíba	1
Minas Gerais	31
São Paulo	1
Rio Grande do Sul	1
Matio Grosso	2
Goiás	2
Total	81

The bulk of the Brazilian tin production comes from five mining operations in the Rondônia district and adjacent areas in Mato Grosso and Amazonas; a minor amount comes from mines in Minas Gerais. The remainder of the mines listed above have little significant production or none, and some may yield cassiterite only as a co-product with some other mineral.

Reserves and resources potential

Official published figures (DNPM 1972-a, p. 39) for cassiterite reserves of Brazil as listed below apparently reflect only those amounts that have been reported by mining concessionaires, resulting from their exploration activities, and do not reflect the true magnitude of tin reserves and resources.

	Cassiterite reserves metric tons (1 m.t. equals 1.1 s.t.)			
	Proved	Probable	Possible	Grade
Rondônia province	43,398	9,763	9,166	66% Sn
Ceará	-	-	20	NA
Pernambuco	314	-	-	NA
Minas Gerais	3,680	377	187	NA

Rio Grande do Sul	-	13,000	-	NA
Goiás	907	-	-	NA
Sub-total	48,299	23,140	9,373	

TOTAL all categories 80,812

Reserve figures for cassiterite given in the geological and mining literature of Brazil as well as in unpublished written communications from Brazilian geologists indicate a greater magnitude than do the official figures above, and in effect reflect the probable magnitude of potential resources. These figures are presented in summary form below and are discussed in the descriptive text for each district or deposit.

Cassiterite concentrate resources in metric tons
(1 metric ton equals 1.1 long tons)

	Proved	Probable	Possible	Percent Grade
Rondônia	160,000	--	--	66 Sn
Goiás	46,000	--	50,000	50-70
Minas Gerais	3,680	318	186	NA
Rio Grande do Sul	--	13,000	--	NA
São Paulo	NA	NA	NA	NA
Paraíba, Rio Grande do Norte, Ceará	NA	NA	NA	NA
Bahia	NA	NA	NA	NA
Amapá	--	16	--	NA
Sub-total	209,680	13,317	50,186	

TOTAL ---------- 273,000 tons of concentrate with 66 percent tin.

The known resources of tin in Brazil places it at present among those nations with substantial reserves. The following figures (USBM, 1970) provide a comparison of Brazil's resources with those of selected other countries.

	Tons of tin	
	Metric	Short
Brazil	180,000	200,000
Thailand	1,406,000	1,557,000
Bolivia	490,000	540,000
China	505,000	555,000
Nigeria	87,000	96,000

Refined tin production

In 1971 five smelters produced tin in Brazil, (Ransome, 1972) as follows:

Company	Location	1971 production tons refined tin
Companhia Industrial Fluminense	Manaus	802
Companhia Industrial Fluminense	São João del Rei	517
Best Metais e Soldas, S.A.	São Paulo SP	small
Comercio e Industria de Metais-ARPA	Rio de Janeiro	nil
Bera do Brasil Metalurgia e Comercio de Metais, Ltda.	São Paulo, SP	1,000
Companhia Estanifera do Brasil	Volta Redonda	831
	TOTAL	3,150

The Companhia Estanifera do Brasil, S.A., has an annual production capacity of 6,800 metric tons of tin ingots at its smelter at Volta Redonda in the state of Rio de Janeiro.

Principal producers of tin in Brazil

Company	Producing from:
Companhia de Estanho São João del Rei Rua Visconde de Inhaúma, no. 65, 4 Andar, 20000, Rio de Janeiro, GB	São João del Rei, Minas Gerais

Companhia Estanifera do Brasil Rua do Carmo, no. 43, 1 andar 20000, Río de Janeiro, GB	Santa Barbara, Rondônia Ipameri, Goias
Companhia Industrial Fluminense, Avenida Presidente Wilson, no. 165 20000, Rio de Janeiro, GB	Rondônia
Companhia de Mineracão Jacunda Avenida Presidente Wilson, no. 165, 20000, Rio de Janeiro, GB	Igarapé Prêto, Mato Grosso
Companhia de Mineracão São Lourenco, Rua Guilherme Moreira, no. 235 69000, Manaus, Amazonas	Igarapé Prêto, Mato Grosso
Macisa Comércio e Industria Avenida Sete de Setembro, 78900, Pôrto Velho, Rondônia	Rondônia
Mineracão Angelim, Avenida Sete de Setembro, no. 740, 69000 Manaus, Amazonas	Rondônia, Amazonas
Mineracão Aripuanã, Rua Haddock Lobo no. 578 01414, São Paulo, SP	Igarapé Prêto, Mato Grosso.
Mineracão Brasiliense, Rua Pedro II, no. 601 Pôrto Velho, 78900, Pôrto Velho, Rondônia	Santa Barbara, Rondônia

Exports, imports, and consumption

In 1971 Brazil exported 1,049 tons of refined tin ingots, primarily to Argentina. In the same year for the first time it exported cassiterite concentrate--10 tons of it. In that year it imported 1,423 m tons (1,566 short tons) of cassiterite with a CIF value of U.S. $2,700,000. Consumption of tin metal in Brazil in 1971 was 3,043 m tons (3,347 short tons) derived from both imported and nationally produced cassiterite concentrates.

TIN DEPOSITS

Territory of Rondônia

The largest tin resources of Brazil are the cassiterite placers located in the Territory of Rondônia in western Brazil. The principal population center of the Territory is the city of Pôrto Velho on the Madeira River. Access is by daily scheduled airplane from Manaus, or São Paulo and Rio de Janeiro; by road through Mato Grosso into south Brazil; and by boat on the Madeira and Amazon Rivers. A recently completed road west of the Madeira River connects Pôrto Velho to a point on the south bank of the Amazon River across from Manaus.

Cassiterite was first discovered in Rondônia in 1952, through the curiosity of a prospector (garimpeiro), in the heavy mineral concentrates of diamondiferous gravels of the Machadinho River, a tributary of the Roosevelt River. The discovery soon aroused the interest of other prospectors in the region and further search was undertaken, particularly within northern Rondônia where most of the cassiterite is now mined. Some production likely started immediately, but only in 1958 was some small production first reported (Lobato et al, 1966). Production gradually increased, despite the use by prospectors of primitive mining methods, and tin became an important mineral resource of Brazil, the annual production by 1970 was about 5,100 tons (5,610 short tons) of concentrate.

In March 1971, the Brazilian government, in a move to assure greater production efficiency suspended the small-scale, hand-operated

cassiterite placer operations (garimpos) of Rondônia. Mining permits were issued only to companies demonstrating sufficient capacity for installing equipment and carrying out mechanized operations. Following a period of lower production in 1971, when only 3,453 m tons (3,798 short tons) of concentrate were shipped, while companies were being organized for more effective operations within larger concessions, the rate of production steadily increased to about 4,000 tons (4,400 short tons) annually by May 1972. By that time, interest in development of the tin deposits had grown so that 12 mining groups were active, made up of a total of 66 mining companies, Brazilian and foreign, plus 22 independent companies and 10 unassociated individuals; this totaled 98 legal entities with exploration rights or applications and mining concessions in the deposits. The magnitude of the areas for which concessions have been applied or have been granted may be estimated by the fact that in Rondônia applications may be made by each concessionaire for a right to a maximum of 10.000 hectares (24,700 acres) of ground for each concession.

Location of deposits

Rondônia has an area of 240,000 km^2 (92,640 mi^2). The known cassiterite deposits are in the northern half of the Territory and are in general distributed within three districts: a) the northwest Rondônia panhandle in an area of about 5,000 km^2 (1,930 mi^2); b) the Candeias-Jamari River basin, an area of 10,000 km^2 (3,860 mi^2); c) the headwaters of the Machadinho and Preto Rivers, tributaries of the Ji-

paraná River, within an area of about 7,500 km^2 (2,893 mi^2) (Lobato et al, 1966, geologic map). In June 1972, at least eight mining companies were producing in various placer areas in the Territory, including Companhia Estanifera do Brasil, Industrial Fluminense, Mineração Jacundá, Mineração São Lourenco, Mineração Angelim, Mineração Rocha and Mineração Brasilense (with 50 percent interest of W.R. Grace & Co.). The last named was operating a 4.5 cu. ft. bucket-line dredge at the Santa Barbara mine on the lower Jamari River basin. In addition, the Mineração Aripuanã was operating at two placer areas at Igarapé Prêto on the Madeirinha River a tributary of the Roosevelt River in Mato Grosso just east of the Territory of Rondônia.

Geologic setting of cassiterite deposits

The geology of Rondônia Territory is known only at exploration reconnaissance scale. Rondônia is a remote region of difficult access and scarce exposures, where the rocks are generally deeply weathered and covered by dense tropical forest. Nevertheless, sufficient information is available to determine the geological setting of the source rocks of the cassiterite deposits (Ljunggren, 1964; Lobato et al 1966; Kloosterman, 1967, and Priem et al 1971). The oldest rocks are of Precambrian age of the Brazilian Shield and according to the classification of the DNPM (1972-c; 1972-d; and Ferreira, 1972) include undivided Precambrain (probably includes Precambrian D (1,800+m.y.), Precambrian C (1,300 to 1,800 m.y.) amphibolite, gneiss, and migmatite; Precambrian B (900 to 1,300 m.y.) quartzite and phyllite of the Mutum-

Paraná formation; and Precambrian A (620-900 m.y.) arkose and conglomerate of the Palmeiral formation. These rocks are intruded by bodies of coarse-grained biotite granite and subordinately by granite porphyry and microgranite, rhyolite, and volcanic breccia. The granitic and metamorphic rocks are transected by quartz veins, pegmatites, aplite, and diabase dikes. The age of the topaz-bearing granite with which the tin mineralization is associated, has been reported as between 900 and 1,200 m.y.--Precambrian B (Cordani et al 1968). An age of 980+20 m.y. was determined from dating 10 samples from three separate granite intrusives by Priem and others (1971).

The Precambrian rocks are overlain by sandstone, siltstone, and shale of continental origin of the Parecís Formation of Upper Cretaceous age and by Tertiary and Quaternary sediments.

The source of the cassiterite and of minor amounts of associated wolframite, columbite, and tantalite are greisen zones, quartz-topaz veins, and quartz veins in granitic bodies and, to lesser extent, in the surrounding metasedimentary rocks.

Cassiterite is produced mainly from alluvial deposits located in the northern half of Rondônia. The placers are found on granite bodies or immediately adjacent to them, and also on metasedimentary rocks. The average thickness of the tin-bearing gravels is about 0.80 meter, and the average grade is 1.5 kilograms (3.3 lbs.) of concentrate per cubic meter; the cut-off grade for mining is 0.5 kilogram (1.1 lbs) per cubic meter of gravel. Wolframite, columbite, and tantalite are

reported in the concentrates but no published information is available on quantities present and no production of these minerals has been reported from the Territory.

There is no record of any mining of the vein material. At the Santa Barbara mine there are two joint-fracture sets, trending NE and NW, in which cassiterite-bearing quartz veins are as much as 15 cm. wide (5.85 in). On the slope of the granitic intrusion east of the dredging operations at the mine, the quartz veins are in a fine-grained granite saprolite. All the eluvium on the slope with its contained cassiterite was being bulldozed (June 1972) and run through sluice boxes for recovery.

Production, reserves, and resources potential

The bulk of Brazilian production of cassiterite concentrate comes from the Territory of Rondônia. The total national production in 1971 reported by DNPM (1972-a, p. 39) was 3,453 m tons (3,798 short tons) of concentrate containing 66 percent tin. The DNPM (1972-d, p. 33) has published the following estimates of future production of cassiterite concentrates from Rondônia:

Year	Metric Tons	Short Tons
1972	5,000	5,500
1973	7,000	7,700
1974	9,500	10,450
1975	12,000	13,200
1976	15,000	16,500

Official figures published by the Brazilian government (DNPM 1972-a p. 39) for reserves of cassiterite concentrate containing 66 percent tin in Rondônia are as follows:

Metric tons
(One metric ton equals 1.1 short tons)

Proved	Probable	Possible	Total
43,398	9,763	9,166	62,927

These figures however, are those reported to the DNPM in official reports by mining companies holding exploration rights or mining concessions and largely represent only those reserves that have been developed on specific properties. In 1966 the DNPM published (Lobato et al, 1966 p. 146) a reserve figure for Rondônia of 3 millions tons (3,300,000 short tons) of concentrate containing 65 percent tin. Other figures reported are 300,000 tons (330,000 short tons) (McCrary, 1972, p. 82). In the opinion of geologists of the DNPM and of CPRM now working in Rondônia, the magnitude of total reserves of cassiterite concentrate is about 160,000 tons (176,000 short tons) containing 66 percent tin. This is for all the areas of Rondônia known to have deposits or occurrences of cassiterite, but is mainly for the northern part of the Territory where CPRM geologist are engaged in a project of field evaluation and mapping of the deposits.

The tin resources of the region might be considerably larger than the present estimate if one takes into consideration the potential for cassiterite in geologically similar areas in southern Rondônia and in the areas east of the Territory in Mato Grosso and in Amazonas. The CPRM plans to undertake reconnaissance investigations in an area of 70,000 km^2 (27,020 mi^2) in southern Rondônia where cassiterite is reported. Progress in field investigations awaits pacification of

local Indian tribes. Investigations are actively under way to the east of Rondônia in Mato Grosso. Mining was started in 1972 in two or more areas on the Igarapé (creek) Prêto on the Madeirinha River a tributary of the Roosevelt River in Mato Grosso (Ransome, 1972). One of the major engineering construction companies on the Amazonian road system has applied for exploration rights for cassiterite in a large tract in the headwaters region of the Aripuanã River in the State of Amazonas (White, 1973).

Minas Gerais

Location of deposits

The principal cassiterite deposits of Minas Gerais are located in the São João del Rei tin district, an area 40 km (24.86 mi) east-west by 30 km (18.64 mi) north-south in the southern part of the state. The city of São João del Rei is located 120 km (74.56 mi) air line south of Belo Horizonte.

Geologic setting of cassiterite deposits

The cassiterite deposits of this district, located west of the city of São João del Rei, are in alluvial gravel and in pegmatite cutting gneiss and subordinately in greisen zones in gneiss adjacent to the pegmatites (Abreu, 1962). The metasedimentary rocks of the area include gneiss, amphibolite, and biotite schist. These rocks are shown on the geologic map of Brazil as undivided Precambrian (DNPM 1972-c). Age determinations reported by Belezkij (1956) are 1,670 m.y.

for gneiss, and about 1,065 m.y. for the staniferous pegmatites which are cut by another generation of non-tin-bearing pegmatites dated at 375 m.y. Economic minerals found in the pegmatites are cassiterite, columbite-tantalite, microlite, and spodumene.

Production, reserves, and resources potential

The principal production is from the Nazareno pegmatite located on the Fazenda Volta Grande near the Rio das Mortes, worked by the Companhia de Estanho de São João del Rei. This pegmatite is 1,700 meters (5,577 ft.) in length and ranges from 3.5 to 31 meters (11.5 to 101.7 ft.) in width. About 1 kilogram (2.2 lbs.) of concentrate per cubic meter is recovered (1.09 cu yds) from weathered rock, containing 68 percent cassiterite, 15 percent tantalite-columbite and 10 percent microlite (also called djalmaite in this district). Natural concentrates from the district may contain as much as 85 percent cassiterite, 10 percent tantalite-columbite, 10 percent microlite, and 40 percent ilmenite (Guimarães, 1956).

Cassiterite has been produced from a number of localities in the São João del Rei district since operations were started in 1942, but production has probably never exceeded a few hundred tons per year. It is estimated on the basis of an evaluation by Abreu (1962), that about 5,000 tons (5,500 short tons) of refined tin have been produced from concentrates from the district. Mining production has been decreasing gradually and is estimated (A. L. Ransome, written communication) in 1971 to have been no more than 150-200 tons (165-220 short tons) which was smelted by the Companhia Estanifera do Brasil at its

plant at Volta Redonda in the State of Rio de Janeiro. Production from the district has not been sufficient to supply the smelter of the Companhia Industrial Fluminense located near São João del Rei. In 1971, this plant produced 517 metric tons (568 short tons) of tin from concentrates trucked from Rondônia.

Published reserve figures (DNPM 1972-a) for cassiterite ore (tenor not specified) from Minas Gerais are 3,680 tons (4,048 short tons) proved, 317 m tons (349 short tons) probable, and 187 m tons (206 short tons) possible. The bulk of this reserve, although not so specified, is probably from the São João del Rei pegmatite district.

Cassiterite has been produced in minor amounts from placers derived from pegmatite in the Municipios of Araçuaí, Itinga, Salinas, and Virgem da Lapa in northeast Minas Gerais. Extraction has been by prospectors (garimperiros) and likely has not exceeded a few tons per year. The Companhia Estanifera do Brasil is reported to have undertaken development work on some of the pegmatites (Abreu, 1962, p. 468).

In 1971 23 requests for exploration rights were registered with the DNPM for cassiterite deposits in Minas Gerais. Only three were granted. However, there are 31 registered cassiterite mines in the state.

Goiás

Location of deposits

The principal cassiterite deposit in Goiás, the Ipamerí deposit, is 27 km (16.78 mi) south of the town of that name in southern Goiás,

near the village of Paredão, 160 km (99.4 mi) airline southeast of the city of Goiânia. Recently discovered deposits are located near Cavalcante and Monte Alegre de Goiás in eastern Goiás.

Geologic setting of the Ipameri deposit

The Ipameri tin deposit is in greisenized metasedimentary rocks of the Minas group, Precambrian B (900 to 1,800 m.y.) age (DNPM 1972-c and Guimarães and Dutra, 1964), near the contact with a stock of granitic rock. The cassiterite ore with associated tourmaline was emplaced as lenticular shoots in the plane of schistosity of the rock. The deposit is on a northeast-plunging anticline and the mineralized rock has a strike length of 900 meters (2,953 ft) of which only about 300 meters (984 ft) has so far been considered minable ore (Alves, 1965).

Production, reserves, and resources potential

Based on evaluation by Alves (1965) and including ore mined by the Companhia Goiâna de Comercio e Mineração until suspension of its operations in 1967, it is estimated that up to that time, about 2,000 tons (2,750 short tons) of cassiterite concentrate containing 60 percent tin was produced from the Ipameri deposit. In the later years production probably was no more than a few tons per year, extracted by garimpeiros from eluvial and alluvial deposits. In 1973 the Companhia Estanifera do Brasil was modernizing mining installations and constructing a new mill to undertake expanded production.

In 1972 the DNPM (1972-a, p. 39) showed proved reserves of 907 tons (997 long tons) of cassiterite in the Ipameri deposit. Figures

published in 1965 (Alves, 1965) based on DNPM drilling on the deposit show proved reserves of 46,000 tons (50,600 short tons) of ore containing 50 to 70 percent cassiterite. This is calculated to a depth of 132 meters (433 ft) in an exposure length of 380 meters (1,247 ft) and a width of less than 10 cm (3.94 in). Assuming that the cassiterite-bearing rock persists for the remainder of the 900-meter (2,953 ft) strike length of the mineralized zone and to the same depth and width, the total tin resource potential of the deposit is of the magnitude of 100,000 tons (110,000 short tons) of ore.

Cavalcante and Monte Alegre de Goiás deposits

Early in 1973 cassiterite was discovered by prospectors in the Serra Branca near Cavalcante in eastern Goias (Lat. 13°15', Long. 47° 30'). The deposits are in a greisen zone extending for 3 km (1.86 mi) on the east side of a Precambrian circular granite stock 10 km (6 mi) in diameter. Cassiterite is extracted from eluvium and alluvial gravels by prospectors to yield 200 to 250 tons of concentrate monthly (Marques, et al 1973-a, p. 60). Following this discovery, mineral reconnaissance of the region resulted in the discovery of cassiterite in a greisen zone in Precambrian granite near Monte Alegre de Goias (Lat. 13°18', Long. 47°13'), 60 km (37 mi) northeast of the Serra Branch deposit. Associated alluvial cassiterite is found in coarse gravel deposits about 1 meter thick in the Sucuri RIver valley. As much as 600 grams of concentrate per cubic meter of gravel are recovered (Marques, et al, 1973-b, p. 52). The lode deposits extend

from Monte Alegre de Goias toward Campos Belos (Lat. 13°03', Long 46° 53') 50 kilometers to the northeast (Souza, Emiliano C., written commun., 1973). These deposits are within an area in which an airborne magnetometer and gamma ray spectrometry survey of 47,000 km^2 (18,000 mi^2) was completed in 1973 by the Companhia de Pesquisa de Recursos Minerais as part of the Projeto Serra da Mesa (CPRM, 1973 Annual Rept.).

Bahia

Location of deposits

In Bahia the cassiterite deposits from which there has been some production are alluvial placers in the area of Rio de Contas, Livramento do Brumado, and Paramirim in south-central Bahia state (Fig 2).

Geologic setting and resources potential

The cassiterite placers of Bahia have been worked on a small scale by prospectors since the 1930's when tin was discovered in the vicinity of the town of RIo de Contas (Lat. 13°35', Long. 41°47'), In 1940, an attempt was made to find the source rock of the cassiterite in the Rio de Contas area (Barbosa, 1941), the only placer where cassiterite was then known to exist. Although cassiterite was not found in place, Barbosa suggested the source might be in "metamorphosed quartz-porphyry eruptives" cutting the Precambrian Itacolomi quartzite, because local prospectors found topaz to be associated with cassiterite in the placers and he found a source of topaz in quartz veins cutting the quartz-porphyry.

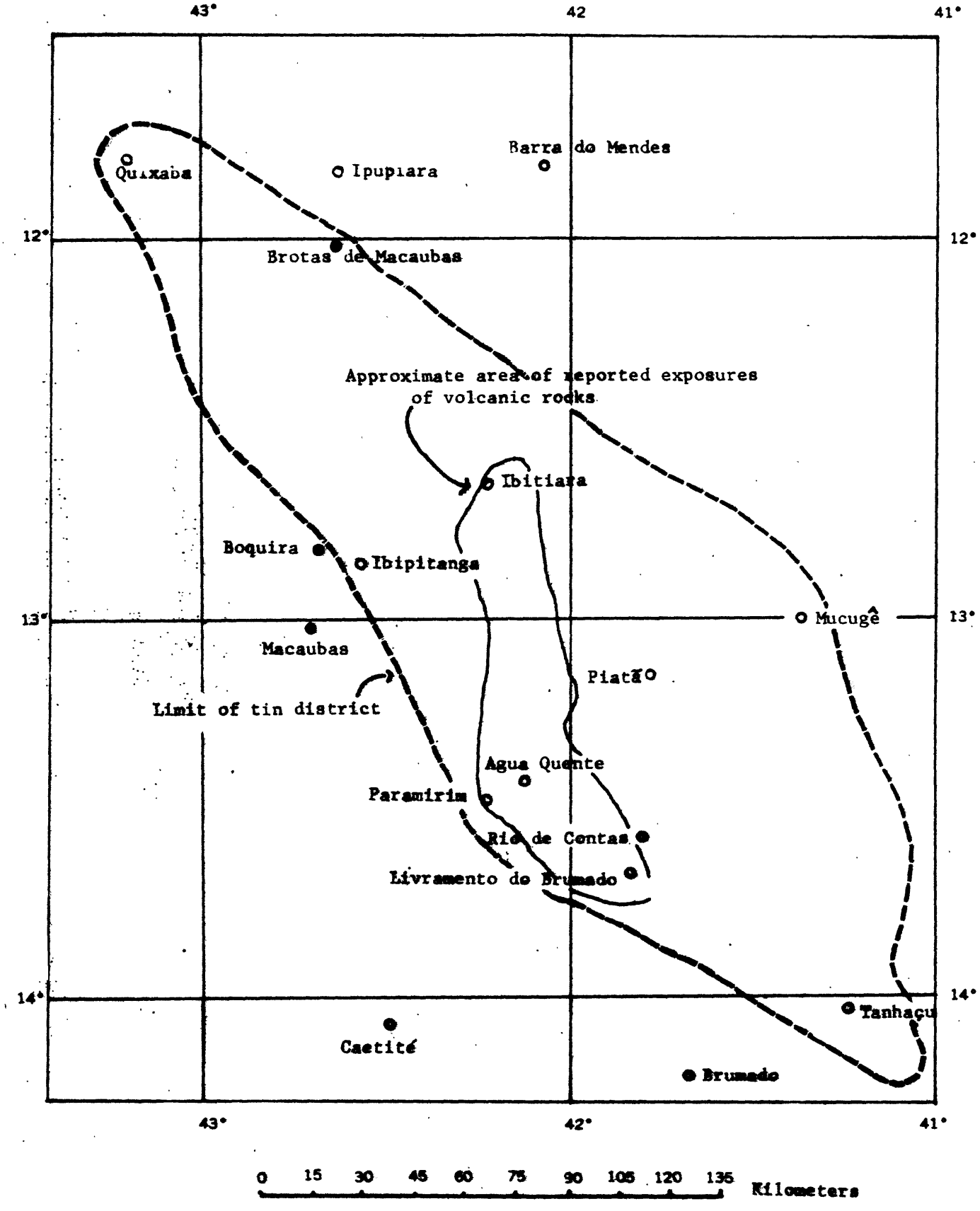

Figure 2. Location of tin district in central Bahia, Brazil

Since 1940, cassiterite has been reported from 34 localities (see table 1) (Marholz, 1966, and Lewis et al, 1972) in a northwest trending belt about 255 km (158 mi) long and about 120 km (75 mi) wide extending from Quixába (Lat. 11°47', Long. 43°12') to Tanhaçu (Lat. 14°02', Long 41°15'). This area is in the northern part of the Serra do Espinhaço and is made up largely of Precambrian B (900 to 1,300 m.y.) Minas Group metasedimentary rocks (DNPM, 1972-c) with which in part of the belt are intercalated volcanic rocks consisting of rhyolite, trachyte, dacite, dacite-porphyry, tuff, and volcanic breccia that commonly are metamorphosed to quartz-sericite schist (Schobbenhaus, 1967 and 1969). These volcanic rocks extend mainly from the Rio de Contas (Lat 13°35', Long. 41°47') area, about 135 km (84 mi) northwestward to the area of Ibitiara (Lat. 12°30', Long. 42°15') (Fig. 2). Scattered exposures of volcanic rock occur northwest of Ibitiára.

Table 1.-Localities in the State of Bahia from which tin has been reported (Marholz, 1966 and Lewis and others, 1972)

	Municipio	District	Location
1	Abaíra	Catolés	Rio Agua Suja
2	Agua Quente	Agua Quente	Benta
3	Agua Quente	Agua Quente	Estreito
4	Agua Quente	Agua Quente	Maranhão
5	Barra da Estiva	Barra da Estiva	Rio de Contas
6	Boquira	Bocuituba	Rio Paramirim
7	Boquira	Boquira	Rio Paramirim
8	Brotas de Macaubas	Brotas de Macaubas	Rio Paramirim
9	Ituacu	Ituaçu	Rio de Contas
10	Jussiape	Caraguatai	Rio Agua Suju and Rio de Contas
11	Livramento do Brumado	Livramento do Brumado	Itaguacu
12	Livramento do Brumado	Livramento do Brumado	Taquari
13	Livramento do Brumado	Livramento do Brumado	Vereda
14	Livramento do Brumado	Livramento do Brumado	Rio de Contas
15	Livramento do Brumado	Livramento do Brumado	Garimpo do Saco
16	Livramento do Brumado	Livramento do Brumado	Serra das Almas
17	Morpará	Quixaba	Rio Paramirim
18	Mucugê	Mucugê	Rio de Contas
19	Mucugê	Mucugê and João Correia	Rio são João
20	Oliveira dos Brejinhos	Bom Sossêgo	Rio Paramirim
21	Oliveira dos Brejinhos	Ipuçaba	Rio Paramirim
22	Oliveira dos Brejinhos	Oliverira dos Brejinhos	Rio Paramirim
23	Paramirim	Canabravinha	Butim
24	Paramirim	Canabravinha	Campos
25	Paramirim	Paramirim	Mata do Fumo
26	Paramirim	Paramirim	Rio Paramirim
27	Piatã	Piatã	Rio de Contas
28	Rio de Contas	Arapiranga	Porco Gôrdo
29	Rio de Contas	Arapiranga	Rio Agua Suja and Rio de Contas
30	Rio de Contas	Arapiranga	Serra do Corrêa
31	Rio de Contas	Rio de Contas	Rio de Contas
32	Rio do Pires	Ibiajara	Rio Paramirim
33	Rio do Pires	Rio do Pires	Rio Paramirim
34	Tanhacu	Sussuarana	Rio de Contas

Misi and Souto (1972) were the first to report finding cassiterite, along with wood tin, in place in the belt of volcanic rocks. The mineral is disseminated and in quartz veins in rhyolite porphyry dikes at the Brejo Santa Teresa hamlet placer locality, 11 km (6.8mi) west of Agua Quente (Lat. 13°25', Long. 42°08') and 13 km (8.1 mi) east of Paramirim. The cassiterite is associated with topaz and "blue quartz" in partly weathered rock. The presence of cassiterite in silicic volcanic rocks in this area provides a guide for geochemical investigations and the possible discovery of additional deposits of cassiterite within the belt of volcanic rocks. It suggests the possibility of a greater tin potential than had previously been suspected in a region where cassiterite had been found before only by chance and where apparently little development or exploration work has been attempted.

The district has produced only a small amount of placer tin throughout the years--no more than a few tons or a few hundred kilograms per year--by prospectors using primitive mining methods. Some of the production probably was not even reported. The DNPM reports only one registered mine in the district, but renewed interest is evident from the fact that in 1971 there were 37 applications filed for exploration rights for cassiterite in this district

Rio Grande do Sul

Location of deposits

The cassiterite deposits of RIo Grande do Sul are in the Municipio de Encruzilhada do Sul in the southern part of the state, 115 km (85 mi) air line southwest of Porto Alegre.

Geologic setting of cassiterite deposits

Within the Rio Grande do Sul cassiterite district of Encruzilhada do Sul are two areas in which the mineral occurs, a northern and a southern area, 30 km (18.6 mi) apart. In the northern area, cassiterite is associated with and subordinate in amount to wolframite. In the southern area in which are found the principal tin deposits there is no wolframite reported. In the two areas the ore minerals are found in quartz veins, greisen, pegmatites, and in alluvial and eluvial deposits (Franco, 1944, and Leinz and Pinagel, 1945). In the northern area cassiterite commonly is in the greisenized granite wall rock of veins to a distance of 10 to 30 cm (3.94 to 11.80 in.) on each side of the vein. The rock contains as much as 0.5 percent tin. Details about this (wolframite) area are given by White (1974).

In the southern area cassiterite has been mined at various times from deposits at Taboleiro, Cerro Branco, Campinas, Santa Barbara, Estreito, Pedro Freitas, and the Aluvião Camaquã (Teixeira, 1937). The rocks in the area include metasedimentary rocks of Precambrian age (620 to 900 m.y.) Porongos group (DNPM 1972-c). These rocks are intruded by granite, aplite dikes, quartz veins, and pegmatites mineralized by tin and to a lesser extent by molybdenum. The cassiterite is generally concentrated in zones of greisenized granite that also contains fluorite and tourmaline and rare topaz. Mineralized quartz veins are associated with greisen zones and have a preferred orientation N. 30° E., and subordinately N. 30° W. The greisen is also

found in the surrounding schist, in which are also found quartz veins to which the tin mineral appears to be restricted. Again, these veins are oriented N. 30° E. and N. 30° W. in two sets of joint-fractures. These veins have considerable length, as much as 5 km (3.1 mi) south of the Campinas deposit, and widths that range to 1.2 m (4.92 ft).

Production, reserves, and resources potential

Cassiterite production from the Encruzilhada do Sul district has been carried on intermittently since discovery of the mineral there in 1903. The first mining was started in 1913 by the Companhia Belga de Estanho de Campinas, S.A., which built a concentrating plant to handle 250 tons (275 short tons) of ore per 24-hour day from the Campinas deposit. In 1928, the Sociedade de Mineração Renner, Ltda., started mining the deposits at Cerro Branco and Taboleiro. The Sociedade Mendes Teixeira e Companhia extracted cassiterite from the Aluvião Camaquã deposit on the Camaquã River. These and other operations appear to have been short lived, production was not high, and there is no published record of exploration and development work from which to determine the tin and tungsten potentail of the district. In latter years no more than a few tons of cassiterite have been produced from the district. The DNPM reports (DNPM 1972-a) only one registered cassiterite mine in Rio Grande do Sul. However, it reports that in 1971 nine applications were made for exploration rights for cassiterite in the state.

Reserves of cassiterite in Rio Grande do Sul (DNPM, 1972-a) are 13,000 tons (14,300 short tons) of indicated ore of unspecified tenor.

São Paulo

Two wolframite deposits in São Paul contain subordinate amounts of cassiterite, the Serra de São Francisco deposit located 20 km (12.4 mi) southwest of the city of Corocaba, and the Inhandjara deposit, 27 km (16.8 mi) west of the city of Jundiaí. No significant tin production is reported from these deposits, nor are figures available on reserves of cassiterite. Details about these deposits are given by White (1974) in the report on tungsten resources of Brazil.

Paraiba, Rio Grande do Norte, and Ceará

Only a few tons of cassiterite are known to have been produced from the pegmatite province of northeast Brazil, largely during World War II, as a by-product of the production of columbite-tantalite. The extraction was done by prospectors using primitive methods (Johnston et al, 1944). Remaining reserves are probably low, and in any case the pegmatites appear to be in such condition as to be uneconomic to mine. Details on the northeastern Brazil pegmatite province are given by White (1974-a) in a report on niobium and tantalum resources of Brazil.

Amapá Territory

Small amounts of cassiterite and tantalite-columbite were produced during World War II from the diamond-gold placer district of the Territory of Amapá (Klepper and Dequech, 1945-a, 1945-b; Dequech and Klepper, 1946). Only a few tons of concentrate were extracted and no production has been reported in recent years. The district is in the upper part

of the Amapari and Villa Nova River valleys in south-central Amapá. The source of the cassiterite is pegmatites in Precambrian metasedimentary rocks. The placers of this district are reported to contain only small reserves, no more than 16 metric tons (17.5 short tons) of cassiterite.

In 1972, the Companhia de Pesquisa de Recursos Minerais conducted a reconnaissance minerals survey of 70,000 km^2 (27,000 mi^2) of this region and the Calçoene River region to the north.

Pará

Numerous cassiterite occurrences are said to have been found in various areas in the Amazon valley, for example, eastward from the Rondônia tin district to the headwaters of the Tapajoz river and even as far east as the Xingú River; and in the Paru and Jarí River valleys, north tributaries of the Amazon RIver, west of the Territory of Amapá where occurrences of placer cassiterite are confirmed. In the Paru River valley, it is reported (Souza, Emiliano C. written commun.) that prospectors annually produce 200 tons of cassiterite concentrate from placers.

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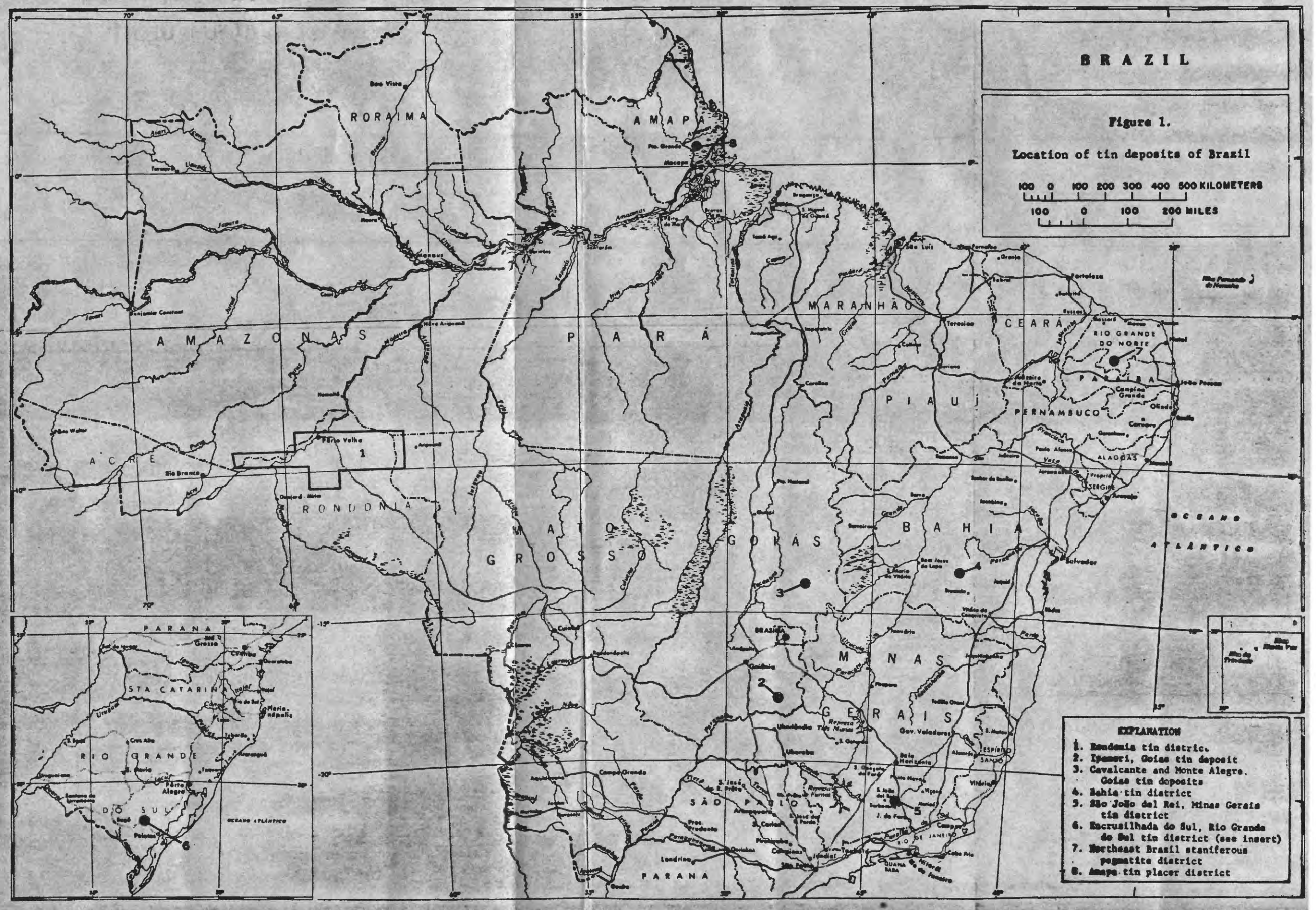
BRAZIL

Figure 1.

Location of tin deposits of Brazil

100 0 100 200 300 400 500 KILOMETERS
100 0 100 200 MILES



EXPLANATION

1. Rondonia tin district.
2. Ipameri, Goias tin deposit
3. Cavalcante and Monte Alegre, Goias tin deposits
4. Bahia tin district
5. São João del Rei, Minas Gerais tin district
6. Encrusilhada do Sul, Rio Grande do Sul tin district (see insert)
7. Northeast Brazil staniferous pegmatite district
8. Amapa tin placer district