UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

A REPORT ON SITE VISITS TO SOME OF THE LARGEST TIN DEPOSITS IN BRAZIL

March 11-25, 1988

By

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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CONTENTS page

LIST OF FIGURES

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INTRODUCTION

Purpose of trip

This trip was undertaken to better understand the geologic setting of tin deposits of Brazil and to enable the USGS to produce a tin resource assessment of the Amazon Basin, including Brazil and adjoining countries. In the past few years, Brazil has become a dominant factor in the international tin market and presently has the world's largest tin mine (Pitinga) and an incredible new tin discovery in Rondônia that is extremely high grade (Ariquemes, Massangana, C-75, and Serrinha are some of the names applied to this area). In addition, numerous mines have been operating in Brazil for the past 10-20 years, though most of them are now abandoned or will be in the next 1-5 years.

Six tin deposits located in Rondônia province and the enormous deposit at Pitinga in Amazonas province were visited between March 12 and 24, 1988. Also, DNPM (National Department for the Production of Minerals) in Brasilia, Porto Velho, and Manaus provided some new facts and figures about Brazilian tin production. The deposits visited included five mines in the Santa Barbara area, a large new discovery near Ariquemes, and the largest tin deposit in the world at Pitinga.

The purpose of this report is to briefly describe the geologic setting of the Rondônia and Mapuera tin districts (fig. 1), the geology of the deposits visited, the mining methods used and, where possible, to provide an estimate of the grade and tonnage of each deposit. The discussion below is organized in the chronological order of the visits. Results of discussions with DNPM and of a visit to a metal processing company are also included.

Acknowledgements

A trip such as the one we were privileged to experience does not take place without a tremendous amount of planning and effort by others. We wish to gratefully acknowledge the efforts of two people in particular. Milton Drucker, who was the Regional Resource Officer, U.S. Department of State, in Rio de Janeiro, made the arrangements in Brazil for us to examine these deposits, as well as the travel and hotel reservations. He accompanied us throughout our visit and his knowledge of Brazil and the mining industry were invaluable. Carlos Oiti Berbert, Diretor, Divisão de Geologia e Mineralogia, Departamento Nacional da Produção Mineral (DNPM) in Brasilia, provided for our transportation from Porto Velho to the Jacundá mines, made available the services of DNPM in Porto Velho and Manaus, and provided for our visit into garimpo C-75 plus the personal guided tour in the garimpo (areas officially designated by the government for mining by *garimpeiros* or prospectors).

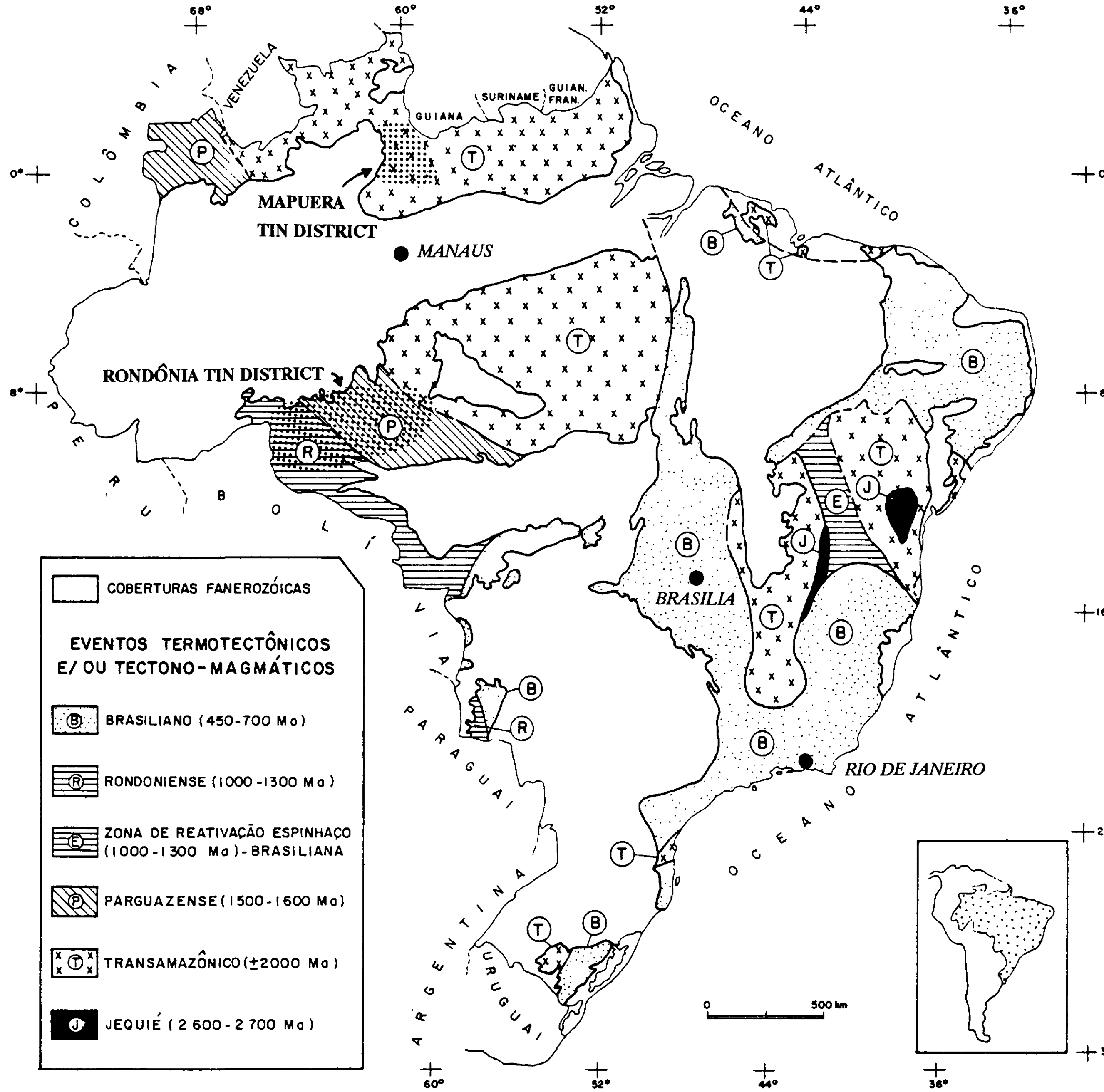


Figure 1. General distribution of the Rondônia and Mapuera tin districts in the Amazon Basin (stippled pattern added by authors). The various major Precambrian orogenic belts are shown in the patterned areas and Phanerozoic rocks in the unpatterned areas (Schobbenhaus and others, 1984).

During our visits to the various mines, many people were extremely generous and helpful. Arnoldo Cardoso, Chief of the DNPM office in Porto Velho, aided us from the time we arrived until our departure from the Rondônia tin district and was extremely helpful in setting up the visit to garimpo C-75. Orlando Eulre de Castro, President of the Cesbra mining company, graciously provided us with accomodations at the Mineração Jacundá mine during our stay in the Rondônia tin district. Ian Dun, Superintendent at Jacundà, and Eduardo Viglio, mine geologist, were very helpful in showing us their mining operations and the geology of the mines. And, Mr. Dun provided us with a superb churrasco (Brazilian barbecue) at the end of the visit. Our trip to Pitinga was made possible by Mr. Otavio Lacombe, one of the directors of Grupo Paranapanema, which owns Mineração Taboca, S.A., the company that operates Pitinga. We were accompanied on the trip by Mr. Lacombe, and Samuel Hanan, Diretor Superintendente of Grupo Paranapanema, Minerações; their hospitality and discussions during the visit were especially interesting and gave us considerable insight into the development of Pitinga, the world's largest tin deposit.

Geologic setting of Rondônia and Mapuera tin districts

Figure 1 shows the general distribution of Precambrian belts in Brazil and the locations of the Rondônia and Mapuera tin districts. The unpatterned areas on figure 1 are underlain by Phanerozoic rocks.

The Rondônia tin district occurs primarily in the state of Rondônia in the western part of the Amazon Basin south of the Amazon River (fig. 2) and includes a large number of producing and abandoned tin mines and garimpos. The tin is produced from placer deposits, greisens, and veins directly related to anorogenic granites referred to as the Rondônia granite suite, which ranges in age from about 1150 to 925 Ma. The granites intruded a gneissic basement (Xingu complex, >1500 Ma) and formed primary deposits as greisen caps, veins, and greisenized gneiss in a shallow intrusive to subvolcanic setting. Typically, the granites form low groups of hills, commonly circular in outline, that rise 20-100 meters above the low-relief jungle terrane.

The placer deposits are very high grade and comprise a gradation from eluvial to colluvial to alluvial sediments. The placer deposits begin on the greisen cap or vein as eluvial material and grade outward into colluvial and alluvial material that extends 3-4 km downstream, suggesting that the source has been or was exposed only a short time and that the erosion cycle lasted only long enough for limited transport and deposition of the tin. This is fortuitous for tin exploration in that the tin is highly concentrated in a small area rather than having been distributed over a great distance along drainages in greatly reduced concentrations. The present surface is probably not much below the Precambrian surface when the primary deposits were formed, because explosion breccias, ring dikes, and associated volcanic rocks in and near the deposits indicate shallow emplacement (perhaps 2-3 km deep). Nearby mountain ranges are underlain by gently dipping late Precambrian sandstones and conglomerates, some of which have paleoplacer tin deposits where they overlie tin granites.

Figure 3 is a generalized geologic map of the area based on interpretation of radar and landsat imagery (SLAR) and photogeology by Thorman and A.I.M. Medina (1974 report prepared for CPRM under USAID/MME work agreement). Of special interest is the fact that an area (fig. 3)

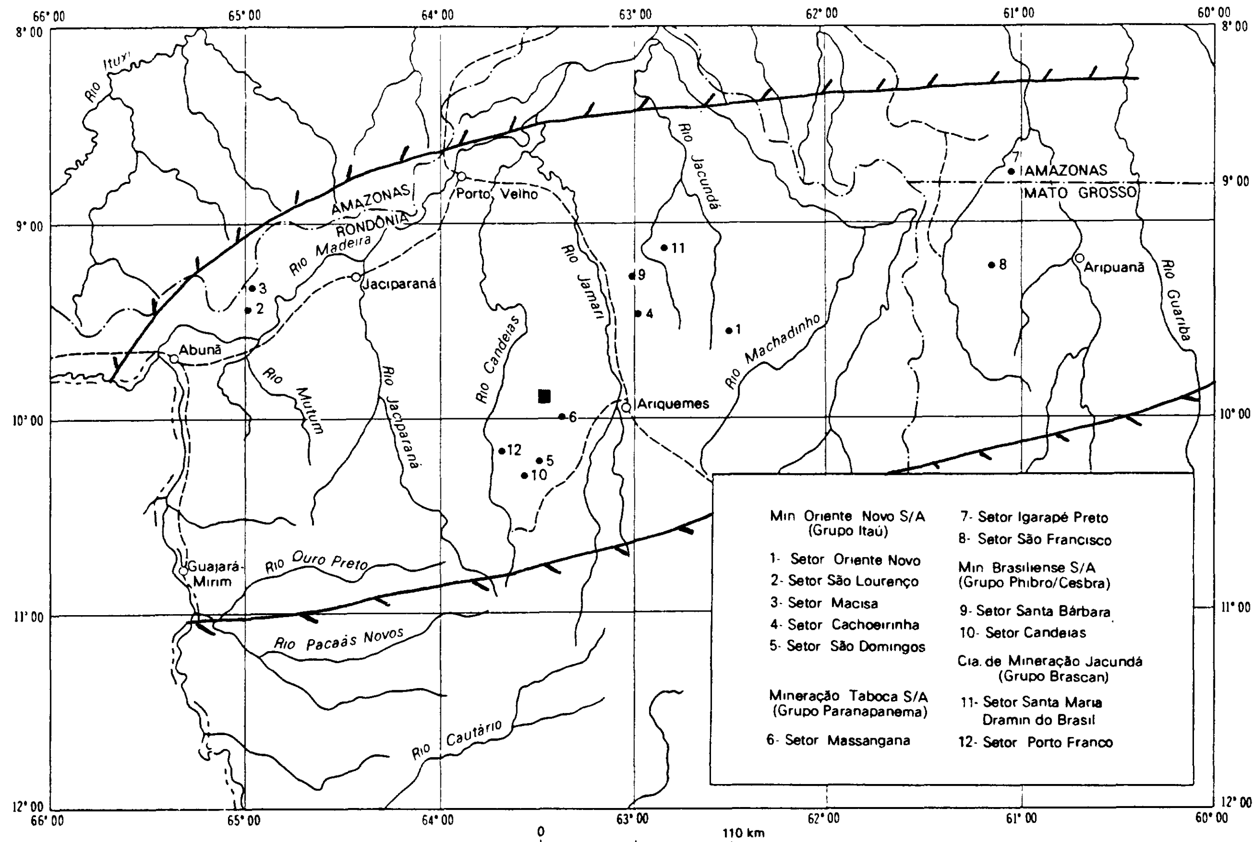


Figure 2. Location of Rondônia tin district; district boundary (hachured line) is generalized. This illustration shows mining concessions of private companies as of 1978 (Leal and others, 1978). The areas we visited are garimpo C-75 (indicated by the solid square) and mines in the Santa Barbara area (number 9).

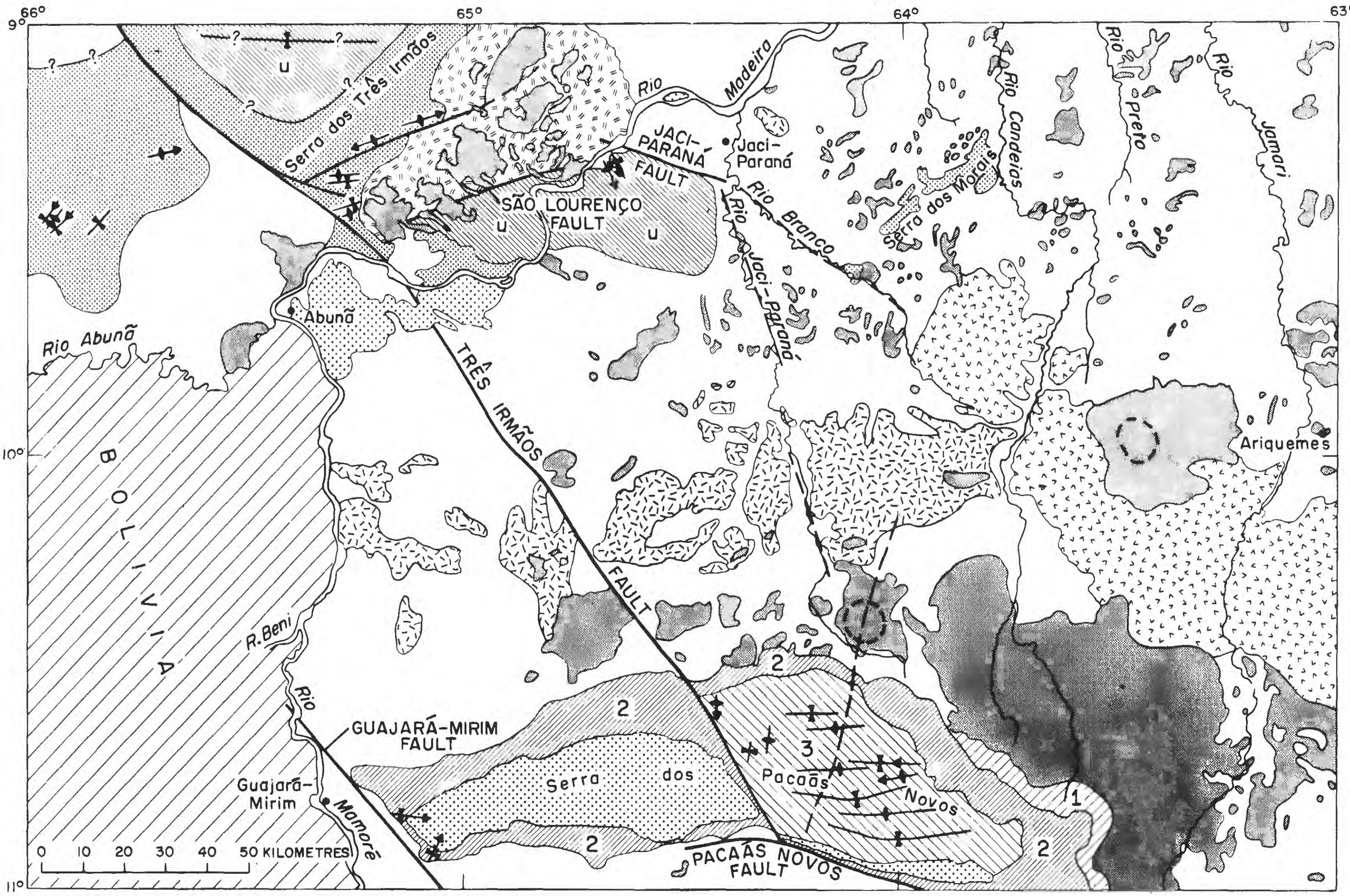
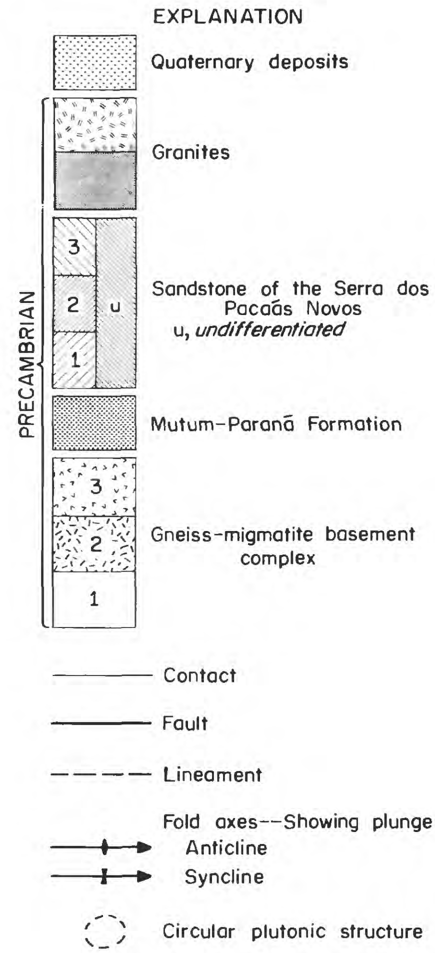


Figure 3. Geologic map of the Rondônia tin district made by C. Thorman and I. Medina (CPRM geologist) in 1974 for CPRM using SLAR, landsat, and photogeology. See figure 2 for the location of the map in relation to the greater Rondônia region.

Figure 3 (continued)



Partial explanation of columnar section:

Granites -- This is the Rondônia biotite granite suite that is the source of the tin in the region. Member 1 (dense stipple pattern) is the most extensive and forms clusters of low hills that rise above the low-relief terrane of the basement gneisses. Member 2 (double hashed pattern) occurs in the northwest and is a region of low rolling hills perforated by the more abrupt hilly terrane typical of member 1. This suite of rocks is 925 to 1150 Ma and is probably older than the two sedimentary units shown; studies since this map was made in 1973-74 indicate the Mutum-Paraná Fm. is uppermost Precambrian and that the Serra dos Pacáas Novos Ss. is only slightly younger than the Rondônia granites.

Gneiss-migmatite basement complex -- This is the Xingu complex, a sequence of feldspathic gneisses, schists, and amphibolites that are >1500 Ma. Three members are recognized based on geomorphic features: member 1 has a very flat to gently undulating surface with a modified dendritic drainage; member 2 forms irregular areas with closely spaced dendritic drainage; and member 3 is characterized by NW-trending ridges suggestive of a layered sequence.

identified from SLAR and marked by a dashed circle, about 50 km west of Ariquemes, falls directly on the site of the recently discovered tin garimpo, a visit to which was one of the main objectives of this trip (discussed in more detail under "visit to garimpo"). The selected area was chosen as being an area of high potential for tin based on the fact that it is characterized by a circular feature similar to those with almost all other tin deposits in the region.

The Mapuera mineral district, which occurs in the states of Pará and Amazonas in the Amazon Basin north of Manaus (fig. 1), was created in 1982 by the Brazilian government to protect the mineral resources of the region against "plundering and untimely mineral activities" and includes Pitinga, the world's largest tin deposit. The general geologic setting of the Mapuera district may extend northward into Venezuela.

A suite of volcanic, intrusive, and sedimentary rocks ranging from approximately 1800 to 1500 Ma. underlie the Mapuera district. The intrusive rocks include three units, an older biotite granite suite about 1700 Ma., a younger biotite-rapakivi granite suite about 1500 Ma., and a mafic-ultramafic series of dikes and sills that is probably related to the younger granites. The older granites intrude a sequence of silicic volcanic rocks; these two may be genetically related. A sequence of continental rocks overlies the older granitic and volcanic rocks and is intruded by the younger granites and mafic-ultramafic rocks. The Pitinga tin deposit occurs in the younger granitic rocks.

MINE VISITS

Potosi deposit

On the afternoon of 3/16/88 we examined the Potosi deposit, which is being mined by Jacundá Mineração. Figure 4 shows the location of Potosi and figures 5 and 6 are, respectively, cross sections of the deposit, and a proposed genetic model. Potosi is reported to be near the end of its economic life. It is a "soft" hard-rock deposit that has been mined by open pit methods. This deposit is a steeply dipping breccia body with plan dimensions of 100 x 250 meters. Emplacement of the breccia appears to have been controlled by the Figueroa lineament and is believed to connect the orebody to the parent biotite granite, which crops out 5 km NW of the breccia pipe. The host rock is the Xingu complex, a series of biotite and hornblende gneisses.

Several greisen types, which exhibit the effects of various degrees of metasomatic alteration, have been mapped. Explosion breccia is prominent in the ore body. This breccia consists of angular fragments of both greisenized and ungreisenized gneiss. Some of the fragments are large blocks. The breccia matrix is topaz. Both tin and tungsten occur in the deposit. A mined-out cassiterite-rich greisen in the core of the ore body contained pods with up to 20% tin. These greisen pods grade outward into a mineralized muscovite greisen and then further outward into a quartz-rich greisen. Cassiterite occurs along relict foliation in breccia fragments of the Xingu rocks, implying that the greisenization occurred before brecciation.

A series of quartz veins that contain tungsten and base metal sulphides are believed, from cross cutting relations, to be the last stage of mineralization. Large fragments of vein quartz (4 to 6 inches) are present

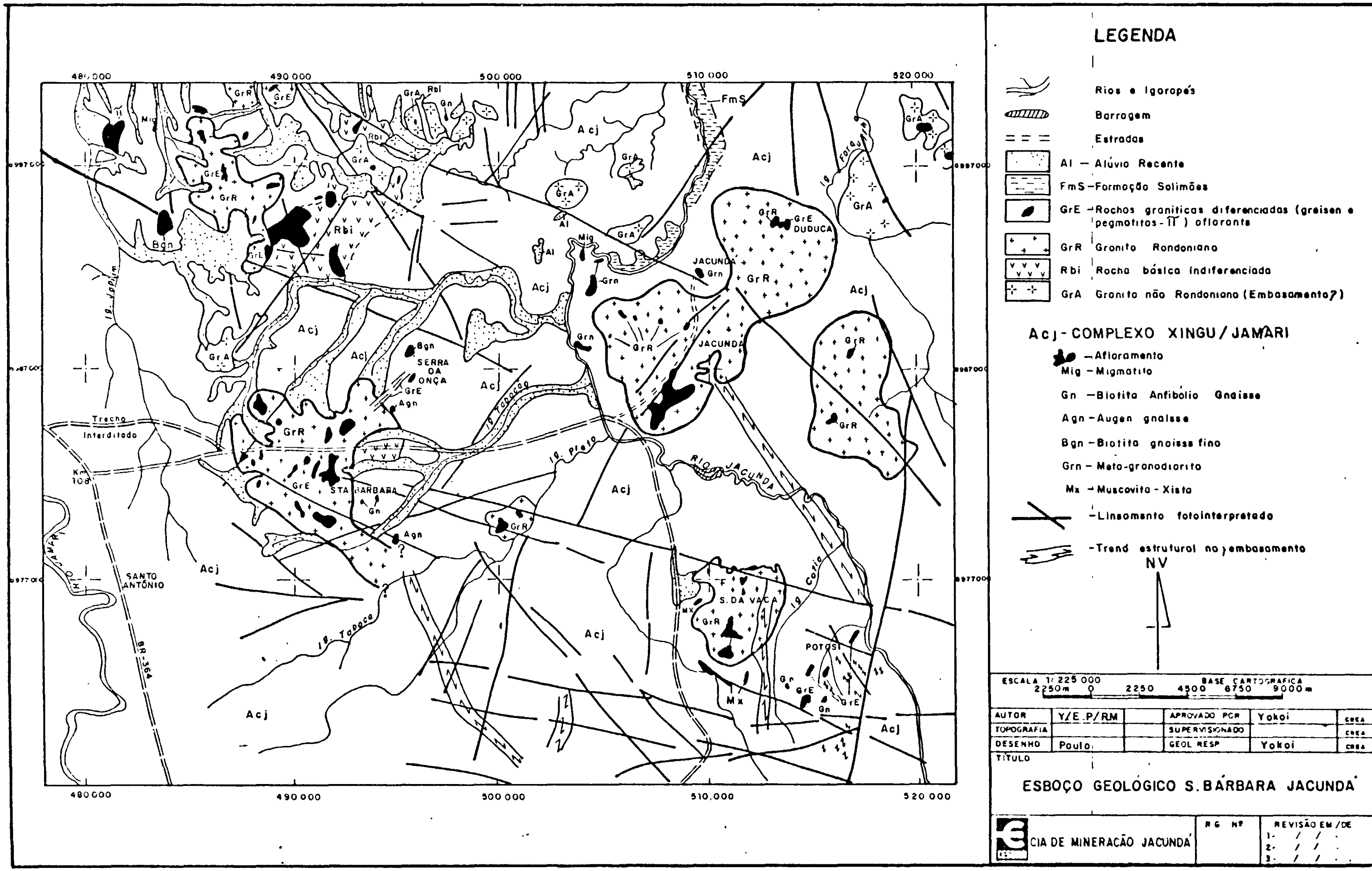
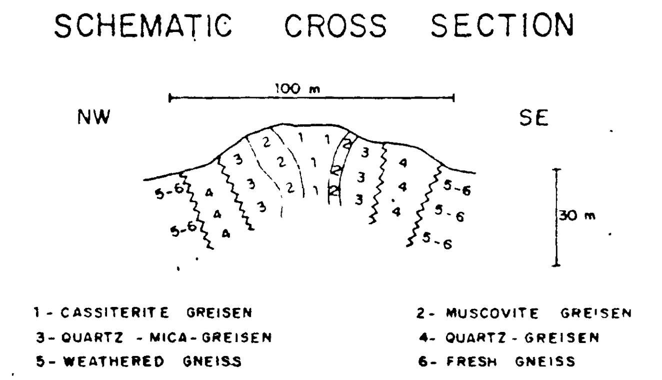


Figure 4. Geologic map of most of the Jacundá mining area showing the location of Potosi (SE corner). Map is from a company report given to us during mine visit.



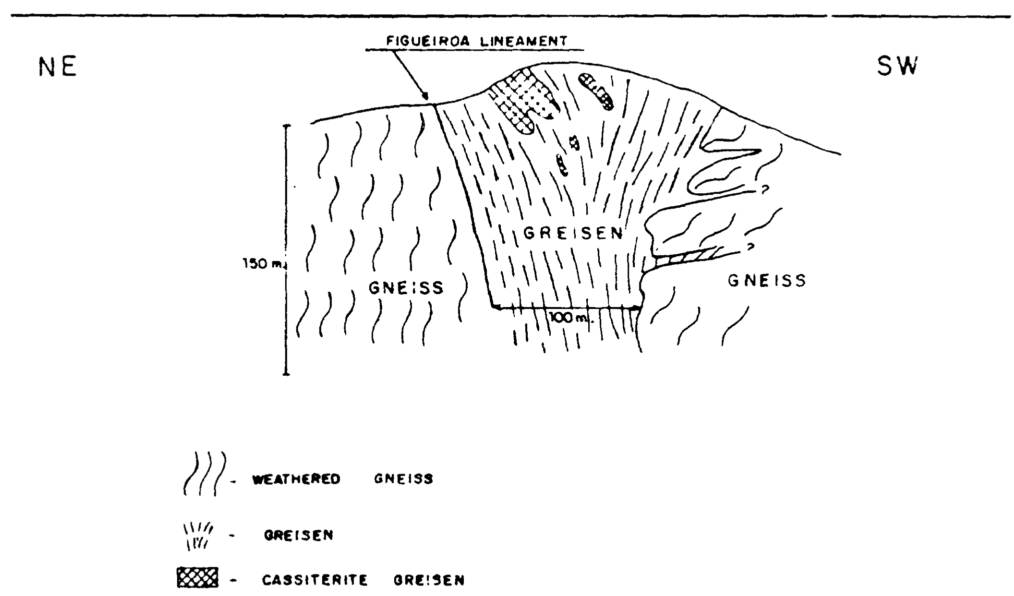


Figure 5. Cross sections of Potosi deposit from Jacundá company report.

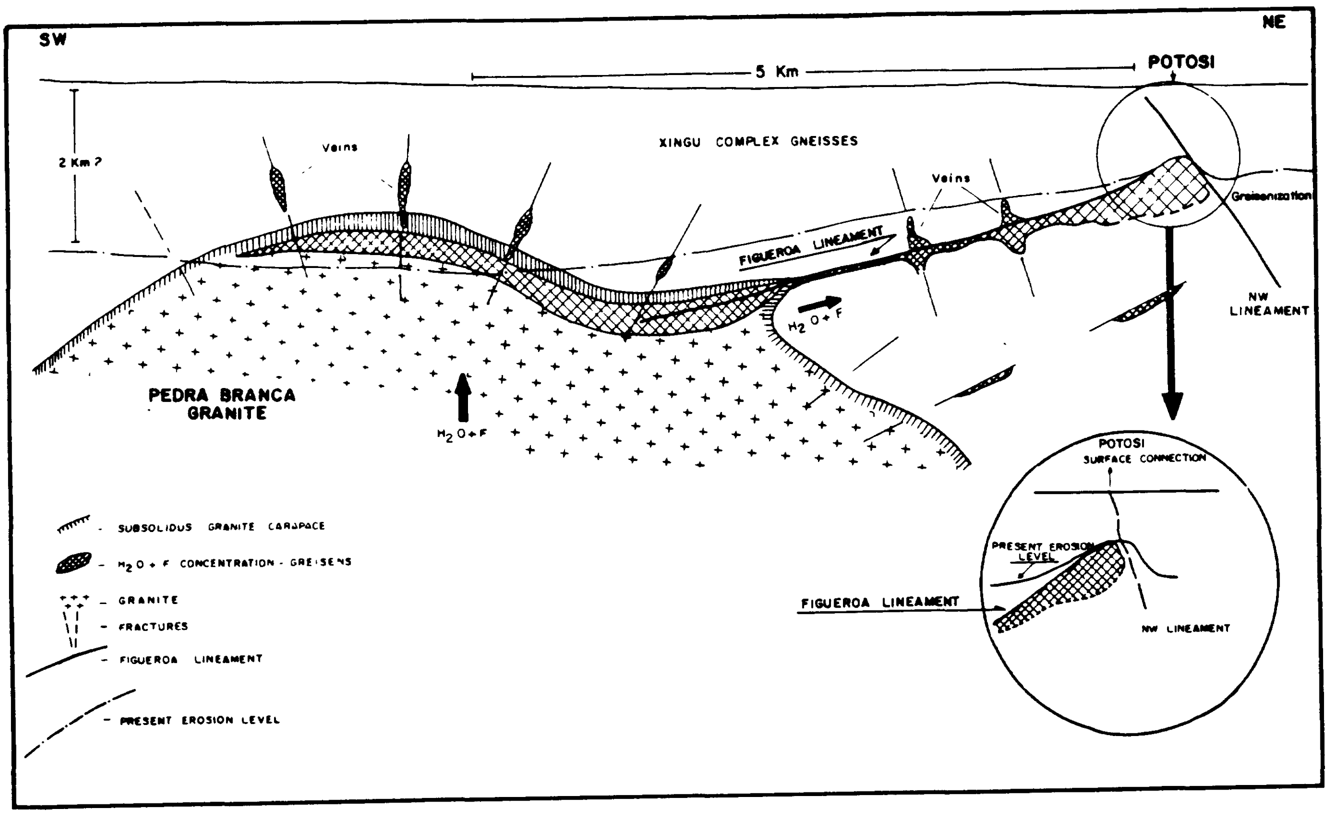


Figure 6. Proposed model for the formation of the Potosi deposit. Jacundá geologists interpret the origin of the fluids that greisenized the Xingu basement gneiss to have come from the nearby Pedra Branca granite along the Figueroa lineament (Yokoi and others, 1987).

in the breccia along the Figueroa lineament. This breccia also contains both mineralized greisenized fragments and fresh gneiss fragments. Brecciation must also have occurred after the emplacement of the late quartz veins. No specific data were obtained on the average grade or cumulative tonnage of this deposit. Twenty-five-ton trucks were being used to haul the ore out of the pit.

Ariquemes/garimpo C-75

On 3/17/88 we visited the large new discovery made in 1987 near Ariquemes, Rondônia (fig. 2). This deposit is referred to by several names, the most common being "the C-75 garimpo"; the other names are Ariquemes (after the largest nearby town), Massangana (the name of a tin/topaz area a few kilometers to the south), and Serrinha (which means 'little hill' in Portuguese, for the adjacent low hills which are the source for the cassiterite). According to one account, the garimpo was discovered in 1987 during lumbering operations where extremely large quartz-cassiterite veins were found in a logging road on the side of a hill. About twenty square kilometers are under siege; placer workings are now being operated by garimpeiros, mostly as small two- to four-man "claims". Several operations involve as many as twenty men. The basal gravel in the alluvium is extremely high grade. The outer parts of the point bars are black in color and contain enough cassiterite to yield as much as 700 kilograms of cassiterite to four garimpeiros per day. This basal gravel averages a meter in thickness and occurs over much of the 20 square kilometers now being worked. It is exposed in pits on the hillsides at depths of 5 to 8 meters.

Current production is estimated to be 7,000 to 10,000 metric tons of tin metal per year produced by a work force of 15,000 garimpeiros. The ore is sold to dealers for about one U.S. dollar per kilogram of contained cassiterite.

The following observations were made during approximately 5 hours of hiking through the C-75 garimpo deposit, a distance of about 3 to 4 kilometers:

1: large quartz-cassiterite veins (3 meters wide) crop out on the hill where this discovery was made. Weathered-out fragments of cassiterite which weigh 10 - 20 kilograms are present on the hillside.

2: large blocks and pieces of similar vein material, as well as terminated quartz crystals, are present in the basal gravel. These quartz crystals are limpid; in the lodes they are not associated with cassiterite, whereas the vuggy-milky quartz occurring in the gravel is associated with cassiterite in the lodes.

3: a breccia underlies a smaller hill. Our guide, who buys concentrate for one of the tin companies, said this breccia is like the breccia at the Potosi deposit. Where examined, the breccia is composed of greisen fragments in a topaz matrix, much like what we saw at Potosi. Adjacent rocks are gneiss.

4: mining equipment consists of several hundred centrifugal pumps, miles of pipe and hoses, and perhaps a thousand sluice boxes. The scene is one which must be a close approximation to the 1849 gold rush in California.

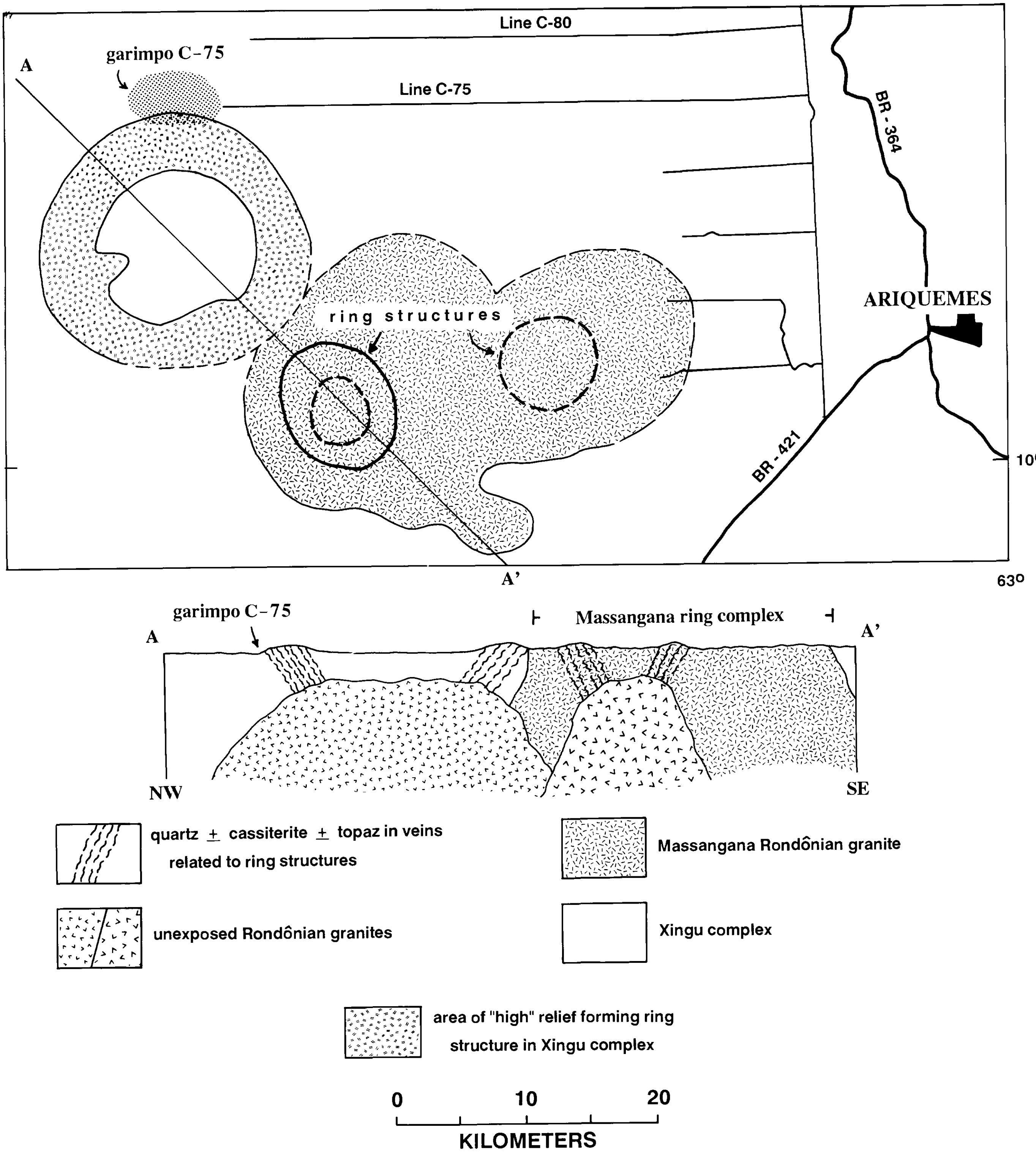


Figure 7. Generalized geologic map by Thorman from SLAR imagery and cross section showing possible model for formation of C-75 garimpo tin deposit. Patterned units in cross section represent various intrusive phases of Rondônian granite suite in the Xingu complex (unpatterned) area. Quartz-cassiterite vein systems indicated by wiggly lines.

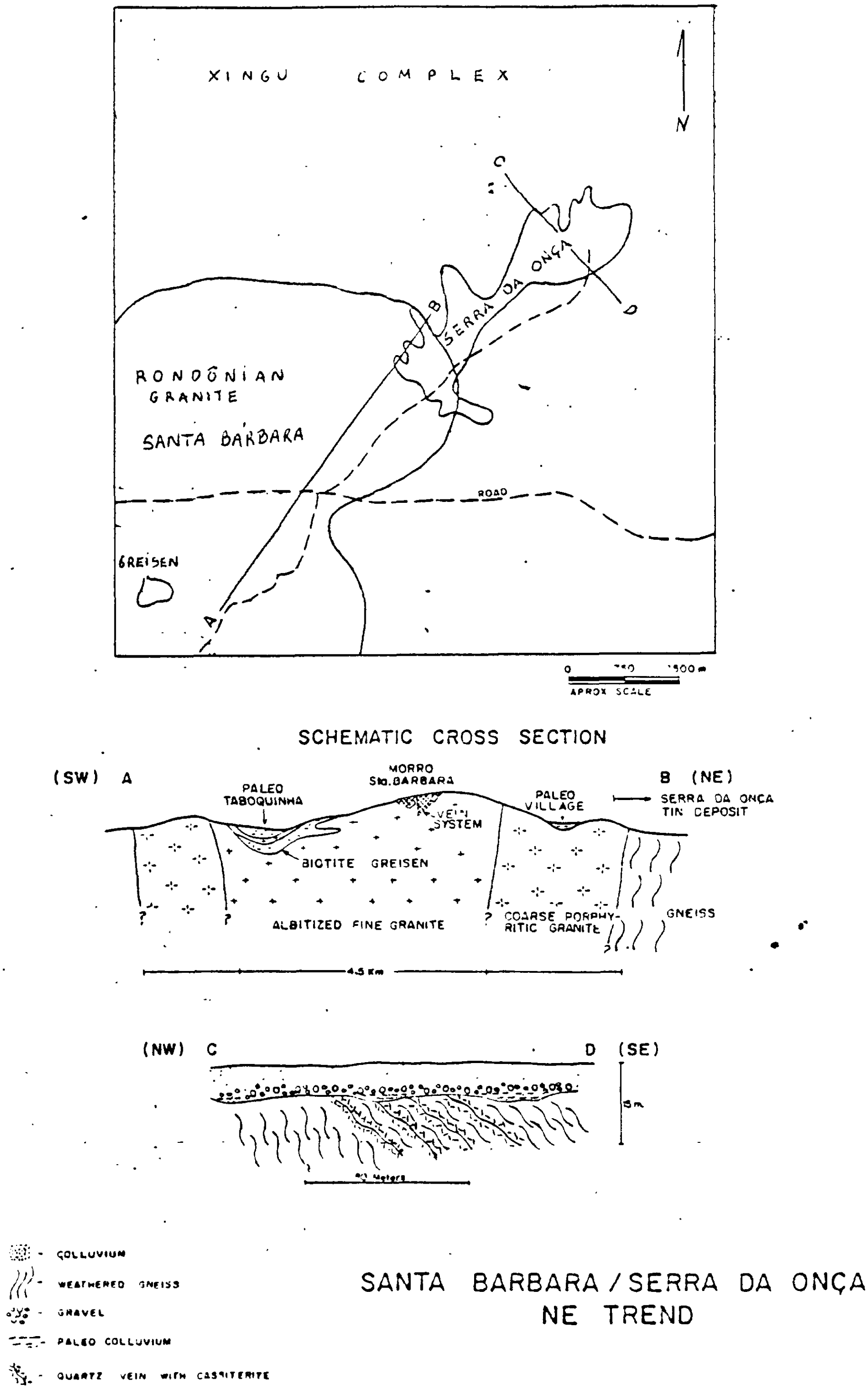


Figure 8. Sketch map from Jacundá company report of the area of the Santa Barbara and Serra da Onça deposits. Section AB at Santa Barbara shows the hard rock greisen deposit, that may be mined in the future (biotite greisen), which is overlain by a paleoplacer deposit in the Taboquinha drainage. Section CD shows the Serra da Onça eluvial/alluvial placer deposit.

5: the mining operation is extremely inefficient. At one operation we saw two garimpeiros panning 200-300 kilograms/day of concentrate from the tailings of a sluice box that was recovering more than 1500 kilograms in 5 hours. At another operation, tailings from one sluice box were being dumped on top of the ore from an adjacent "claim".

As mentioned above, garimpo C-75 falls on the edge of a circular feature. This feature (figures 7 and 8) is 18-20 km across and consists of an inner area 10 km across with very low relief and moderately spaced drainage and an outer ring 3-5 km wide of low hills with 50-150 m of relief that have a northwest-trending fracture pattern like that in the basement to the south. Almost every deposit in this part of the Rondônia tin district is associated with either a ring structure or a circular pluton. This fact was noted in 1973-74 by Thorman when he was preparing a photointerpretation map of the region for CPRM prior to a project by CPRM for DNPM (Projecto Noroeste de Rondônia). The project was a major compilation of the geology of the region, including the preparation of a new geologic map and a listing of the mineral occurrences of the region. In addition, garimpo C-75 occurs within the northern margin of an area outlined as having tin-niobium potential in a 1985 metalogenic map of sheet SC. 20-V-D (1:250,000) prepared by the Companhia de Pesquisa de Recursos Minerais (CPRM) for the Departamento Nacional da Produção Mineral (DNPM). One of the maps in the 1985 metalogenic map series indicates tin anomalies in the Santa Cruz stream, which flows northward through the garimpo C-75 area.

Santa Barbara and Serra da Onça deposits

On 3/18/88 we inspected five ore bodies in the Santa Barbara area owned by Jacundá (fig. 2). These include the Santa Barbara, Serra da Onça No. 1 and No. 2, "the 14th of April", and Mina Poça.

Both hard rock and placer deposits are present at the Santa Barbara mine. The main ore zone is colluvium on the side of a hill below primary greisens (figure 8). The mine geologist indicated that the "main quartz vein" is the main control in the genesis of this ore body. This vein is only 0.1-1.0 meters wide at Santa Barbara, but it can be traced northeastward for about five kilometers where it cuts through the middle of the Serra da Onça deposit. At Serra da Onça this "vein" is an 80-meter-wide vein system.

Several greisen types have been mapped at Santa Barbara. These include muscovite greisen, biotite greisen, and zinnwaldite greisen. These greisens are cut by the "main" quartz vein which also contains base metal sulphide minerals.

Perhaps one of the most important pieces of information collected at Santa Barbara is that there is an aeromagnetic low over the deposit with aeromagnetic highs just off the flanks of the deposit. This is in agreement with geophysical exploration model proposed by B.L. Reed (personal communication).

The Santa Barbara deposit has substantial reserves, both in hard-rock greisens and in colluvium/alluvium placers. The grades in the colluvium and alluvium range from 700 to 900 grams per cubic meter. The greisens examined were weathered but withstood some pounding with a rock hammer before they crumbled. These greisens are being considered for future mining operations, but may need to be drilled and blasted. The mine manager was not happy with having to use such means to obtain ore material. Paleoalluvial material, which forms the basal gravel in the bottom of the paleovalley west of the greisen outcrops, is high grade and contains at least 16,000 metric tons of tin. The paleoalluvial deposit lies beneath 30 meters of cover, which seems to pose more of a problem than having to drill and blast the greisen ore.

Because of the above-mention problems, the Jacundá operations have been moved northeastward 5 kilometers to Serra da Onça, where a thick (20 meters) colluvial-alluvial deposit is being mined. Production appears to be about 100+ tons of tin metal per week. The 300x800-meter area in the jungle has been cleared for mining. The grade of the deposit was said to be about 900 grams per cubic meter. About 60,000 cubic meters are being processed per month, with 95% recovery.

On 3/19/88, the central quartz vein system of the Serra da Onça deposits were examined. This is the same "vein" as the "main quartz" vein in the Santa Barbara deposit. At Serra da Onça, this vein system is 80 meters wide. The mine geologist believes that all of the cassiterite mineralization occurred in this system, which therefore is the source of all cassiterite occurring in the colluvium and alluvium deposits at Serra da Onça. Drill core from 50 meters depth taken from this vein system, contain coarsely crystalline sulfide minerals, chiefly chalcopyrite and sphalerite. The sulfide-rich veins range up to 20 centimeters in width. Cassiterite is abundant and very coarsely crystalline. Single crystals are commonly 3-5 centimeters in diameter.

The Mina Poça deposit is a large open pit which has been in operation for more than 20 years. In the center of the pit, hard bedrock remains in a large knob around which all the material that could be mined by hydraulic jet had been removed. A bulldozer and hydraulic jets feed a large gravel pumping system. Freshly scraped saprolite on the margin of the deposit showed an intricate stockwork vein system. The crosscutting veins are altered to kaolin.

The mine geologist for Jacundá believes that the mineralized exogreisens in most of the deposits mined by Jacundá have a common form in that the cassiterite, where it is not confined to a vein, replaces mafic minerals of the gneissic host rock, such as at Potosi. This relation applies to the augen gneisses as well as the foliated rocks. The original felsic minerals are replaced by topaz and quartz.

Pitinga deposit

On 3/22/88 we were taken by company plane to the world class tin mine at Pitinga in the north central Amazon owned by the Paranapanema Co. This mine will produce 34,000 metric tons of tin metal in 1988; 26,500 metric tons of this will be exported, up from 21,000 metric tons last year. Paranapanema claims to produce 12% of the western world's tin.

The geology at Pitinga is rather simple in that little structural disruption or effects of regional metamorphism have been observed (figure 9). The rocks range in age from 1900 to 1600 Ma and include a thick petrogenetic series of 1900 Ma rhyolitic ashflow and airfall tuffs that is intruded by 1800 Ma granites. The emplacement of these granites was followed by a period of deposition of locally derived sandstones and shales. At

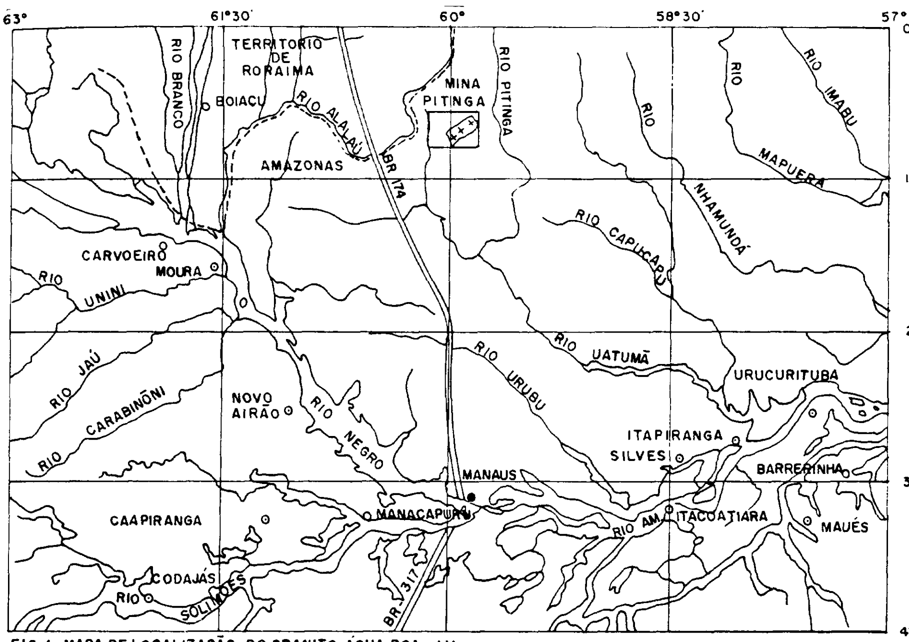


FIG. 1 MAPA DE LOCALIZAÇÃO DO GRANITO ÁGUA BOA - AM.

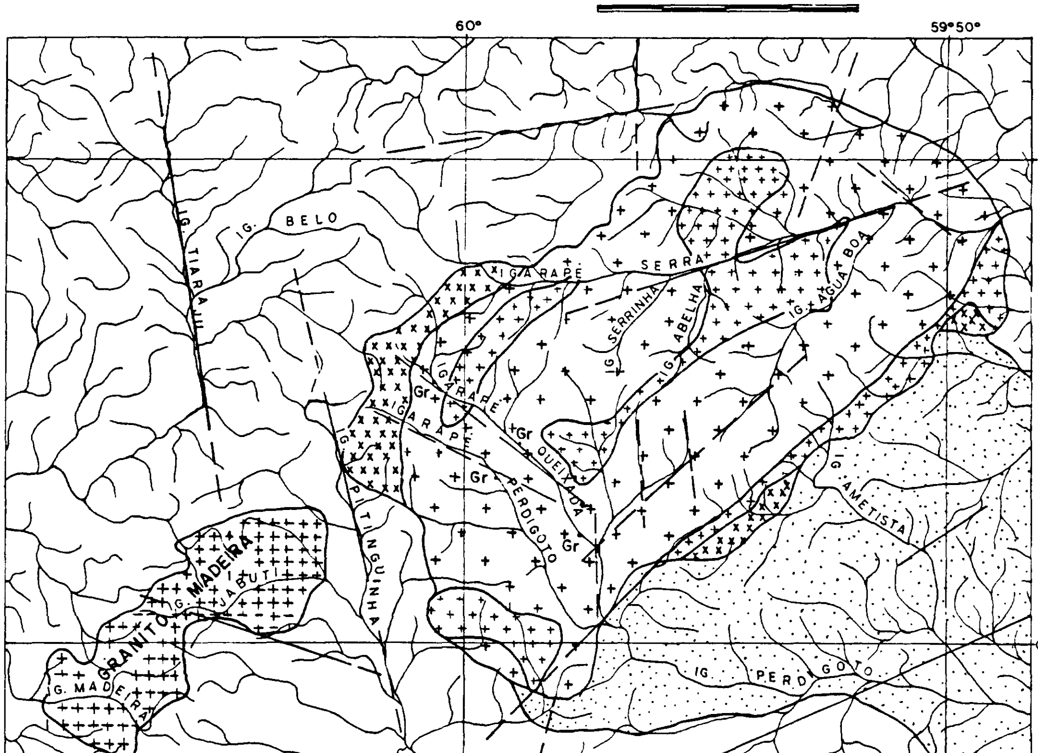


FIG. 2 MAPA GEOLÓGICO DO GRANITO ÁGUA BOA - AM.

LEGENDA

GRANITO ÁGUA BOA

BIOTITA-GRANITO EQUIGRANULAR MÉDIO A GROSSEIRO

GRANITO PORFIRÍTICO FINO

GRANITO GRANOFÍRICO RAPAKIVÍTICO

FORMAÇÃO URUPI

CONGLOMERADOS, ARENITOS, SILTITOS E TUFOS

GRUPO IRICOUMÉ

RIOLITOS, RIODACITOS E TUFOS

0 2 4 6Km.

CONTATO GEOLÓGICO

CONTATO LITOLÓGICO

FRATURA

FALHA

20 ATITUDE DE CAMADA

IGARAPÉ

Gr GREISENS

Figure 9. Location and geologic map of the Pitinga area showing the areal distribution of the Agua Boa granite which is host to the Pitinga tin deposit (centered on the "NI" of GRANITO MADEIRA) (Daoud and Antonietto Júnior, 1985).

about the same time, a series of granites were emplaced, evolving from a rapakivi granite through a porphyritic granite to a subalkaline biotite granite. Greisenization of the biotite granite produced the enormous ore body at Pitinga. Company geologists have divided the Madeira granite, the Pitinga tin deposit host rock, into four phases: a rapakivi granite that makes up ±30% of the pluton and has accessory minerals including fluorite, topaz, and zircon; a biotite granite that makes up ±65% of the pluton and is extremely homogeneous; an altered alkali granite which forms a narrow band encompassing the younger tin-bearing apogranite phase and is a metasomatic product of the rapakivi and biotite granite phases; and an apogranite that was the final phase, bringing in the tin-mineralizing fluids. The apogranite, or greisenized granite, is the primary tin deposit and was the source of the alluvial deposits. The apogranite, or core of the metasomatite, is reported to contain 70% albite. Ore minerals in the apogranite (metasomatite or endogreisen) include zircon, pyrochlore, columbite, tantalite, xenotime, and cassiterite.

The Paranapanema company reports reserves of 500,000 metric tons of tin, niobium, and tantalum each and 2,000,000 tons of zircon to DNPM. The rare-earth content is substantial also. Pitinga is one of the great ore bodies of the world. It is Paranapanema's intention to become vertically integrated and to supply end-use chemicals and metals and to never sell concentrates.

The grade of the alluvial cassiterite ore at Pitinga is said to be more than 2 kilograms per cubic meter. Nineteen dredges are presently working at Pitinga. The smallest dredge has a 20,000-cubic-meter capacity per month and the largest a 200,000-cubic-meter capacity per month. A recovery of 85-92% was claimed. We were told that a plan exists to recover the coarse ore material which now goes out the core of the trammel. Crushing the coarse material would bring the recovery up to 95%; large pieces of rock that contain cassiterite are presently being dumped back in the pond behind this 200,000 cubic-meter-per-month dredge.

The "hard rock" mining operation at Pitinga consists of bulldozing a reddish laterite/saprolite into a hopper, and making a slurry that is processed in the pilot plant. The concentrate produced contains 80% zircon and 20% cassiterite.

As part of our tour, we were shown a cattle ranch which has been cut out of the jungle. We saw chicken farms, orchards, a new hospital, and so forth. Paranapanema is making a pleasant town with modern facilities in one of the remotest places in all of Brazil. Mr. Lacombe said that Paranapanema's investment is about U.S.$250,000,000 so far. They have built two electric power plants with a capacity of 19,500 Kw. The first one is a thermoelectric plant with a 4,000 kW capacity, equal to the use of 60 million liters of diesel, that is powered by wood from the deforestation of the mine area; the second is a hydroelectric plant, with a 10,000 kW capacity, built in 24 months.

PRELIMINARY THOUGHTS ON TIN RESOURCE POTENTIAL FOR THE AMAZON BASIN

Two districts, Rondônia and Mapuera, have major potential for future tin production in Brazil. These districts can be considered as the early and late contributors to Brazil's tin production cycle. Rondônian tin production began in 1965, whereas that of Mapuera commenced in 1982. The true size of the Pitinga deposit in Mapuera is unknown.

Rondônian tin production was initiated in 1965 by garimpeiros. In 1970, mechanized production began and, since 1972, mechanized mining operations have dominated tin production. Since the 1965 discovery of tin, many major deposits have been found in Rondônia, but most are almost worked out. The huge decline in the tin price during the past few years has hastened the closing of several mines in the district. It appeared as though tin mining would slowly end in the district despite considerable exploration effort during the past 4-5 years by several companies. However, the recent discovery of extremely high grade placers at the C-75 garimpo suggests that potential for identification of new deposits still is high. The outlook for additional tin discoveries in Rondônia is excellent. The old adage "when in elephant country, look for elephants" still applies to Rondônia.

The development of exploration models unique to each district is essential to identification of additional deposits in these districts. These models for must include placer deposits. The major difference between the models is the nature of the primary deposit rather than the placer deposits, which typically are spatially related, often with a large colluvial/eluvial "placer" deposit resting directly on the primary deposit. The model for the primary granite-related Rondônia-type deposit includes the following:

- shallow emplacement (a few kilometers deep, at the most);
- commonly has ring fracture system that propagated well above the top of the main pluton;
- major faults controlled locus of pluton emplacement;
- venting of hydrothermal fluids and magma occurred locally along the faults and ring structures;
- mineralized rock is localized in veins in the ring structures and in the major faults and as greisen caps in cupolas of the plutons.

Exploration targets within the Rondônia primary model include: 1) greisen caps on the pluton, as a pervasive alteration in a cupola, or in the form of a very fine stockwork vein system (e.g. Santa Barbara); 2) greisenized country rock (e.g. Potosi); 3) veins along major faults adjacent to plutons, possibly widening into a broad mineralized fault zone (e.g. Serra da Onça); and 4) veins in ring fracture systems that developed during pluton emplacement (e.g. garimpo C-75). The use of SLAR, landsat, and photogeology is very helpful in locating favorable areas, primarily because: 1) the circular plutons typically form circular clusters of low hills, and the plutons typically are sparsely covered with vegetation; 2) the annular geometry of the ring structures is generally readily identified on images; and 3) the major faults are generally indicated by prominent linear features. Stream sediments from drainages issuing from favorable areas should contain anomalous concentrations of tin and tungsten; it may be possible to identify detrital grains of cassiterite, topaz, fluorite, and wolframite.

In contrast, the Mapuera, or Pitinga, primary model would be restricted to major alteration/greisenization within a moderate to large size pluton. With this type of deposit, the model for this deposit type indicates that all granitic bodies, regardless of their geometric expression should be examined. An important exploration guide would be the high Zr, Nb, and Ta content plus intense albitization that typifies the late phase tin mineralization. Although the Mapuera district only has one deposit, Pitinga, it is the world's largest tin deposit and also contains huge reserves of Zr, Nb, and Ta.

The potential for new tin deposits in the well known Rondônia district is very high, as indicated by the recent discovery of garimpo C-75. On the other hand, the potential for the discovery of new deposits in the Mapuera district is less clear because only one deposit has been found. Several factors will slow tin exploration in the near future in the Amazon: the static demand for tin and its probable continued low price; the enormity of the Pitinga deposit will make it difficult for other companies to compete; exploration logistics in the Amazon are difficult and expensive.

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