4. Overview and Analysis of Geological Conditions

4-1 Geological Outline of Brazil

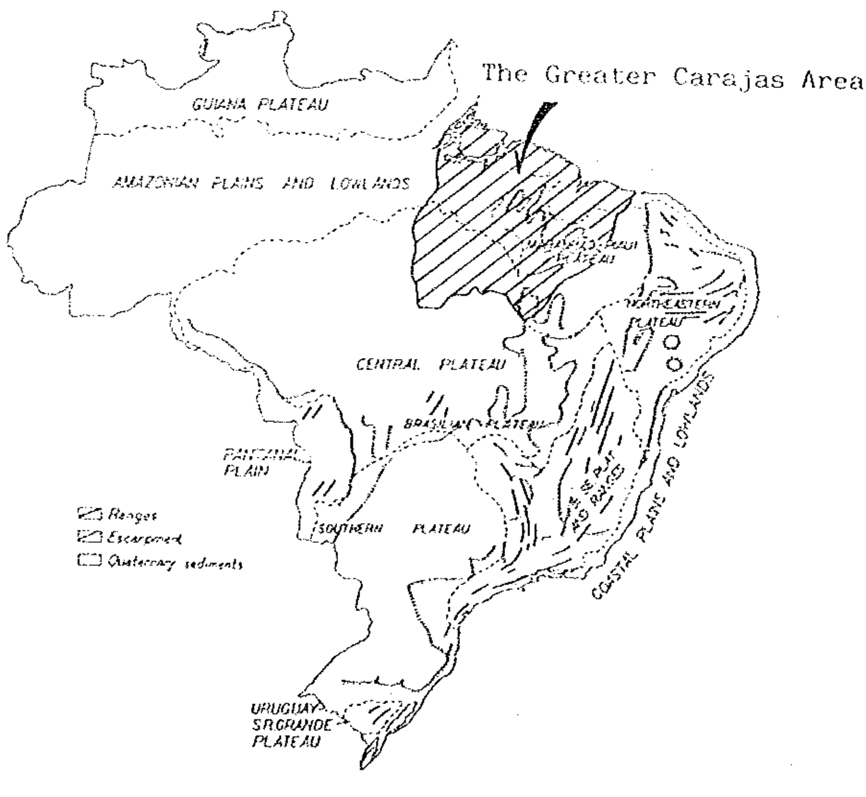
Brazil, located in the central-eastern section of South America, occupies nearly half of the continent. The country has an area of 8,513,844 km^2, of which 36% is Precambrian shield rock, comprising crystalline plateaus with some mountain ranges. Sedimentary plateaus are located between the shield areas comprising 23% of the territory, and the lowlands and plains (elevations below 200 m) make up 41% of the country.

(1) Geomorphic Divisions

In spite of the large area, the general relief of Brazil is relatively low. About 41% of the country is below 200 m, and only 3% is above 900 m. Low erosional surfaces and pediplains between 200 and 300 m comprise 17% of the territory. The land above 600 m (15%) is located in two structural provinces: (a) shield areas uplifted by deep-seated warping; (b) intercratonic sedimentary basins and basaltic plateaus uplifted at the same time as the shield areas by post-Cretaceous epeirogenic movements.

Ab'Saber (1968) identifies six major geomorphic units in Brazil: (a) Guiana Plateau; (b) Brazilian Plateau; (c) Uruguay-South Rio Grande Plateau; (d) coastal plains and lowlands; (e) Amazonian plains and lowlands; and (f) Pantanal Plain (Figure 4-1).

Figure 4-1 Geomorphic Divisions of Brazil (based on Ab'Saber: 1968)

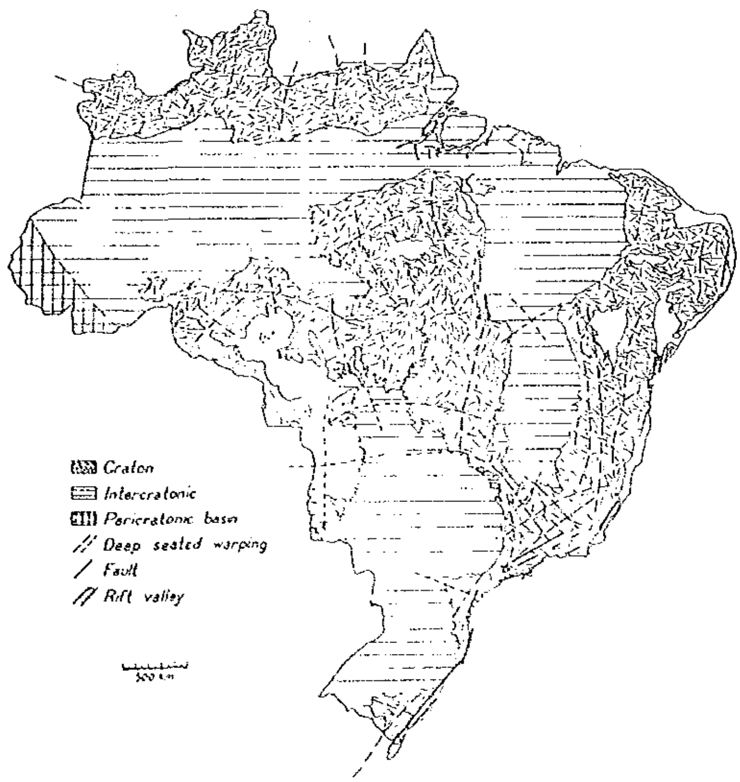


The large Brazilian Plateau can be divided into: (a) Central Plateau, comprising large areas of crystalline plateau and sedimentary plateau (chapadas and chapadoes), such as Roncador and Parecis; (b) Southern Plateau with large areas of sedimentary and basaltic plateaus; (c) Maranhao-Piaui Plateau corresponding to the uplifted sedimentary Parnaiba Basin; (d) Northeastern Plateau of crystalline shield rocks, and isolated sedimentary chapadas; (e) Oriental and South-Oriental Plateau, which is the more complex and mountainous part of the Brazilian Plateau, and which comprises crystalline ranges as well as great escarpments and rift valleys, among other features.

(2) Structural Framework and Geotectonic Divisions

Since the early Cambrian, the Brazilian sedimentary and tectonic history has been controlled by the following major geotectonic units: craton, intercratonic basins, and pericratonic basins (Figure 4-2).

Figure 4-2 Paleotectonic Map of Brazil (Bigarella and Ab'Saber)



The Guiana, Central-Brazil, and Atlantic shields are stable and positive, and little-deformed cratonic units. The Atlantic Shield is large and discontinuous, comprising several sub-units with local names. The cratonic areas have not been disturbed since the Ordovician-Silurian. However, they show deep-seated warping (plis de fond) and faulting. Figure 4-2 shows the main axes of the deep-seated warpings, the main faults and rift valleys, and the intercratonic basins. The Amazonas, Parnaiba, and Parana basins are semi-stable, slightly negative, units between the cratonic areas.

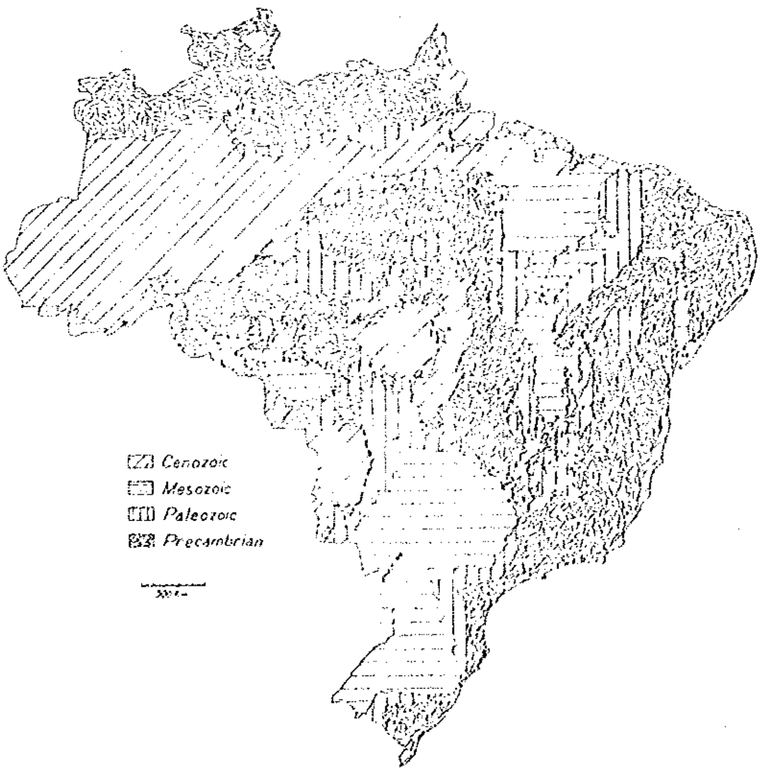
Only a small part of Brazil (Acre and Pantanal) is in the semi-mobile, slightly negative, and semi-resistant South American Pericraton unit. These pericratonic areas, located between the craton and the orogenic Andean belt, are characterized by a large fault system and by extensive Upper Cenozoic sedimentation. The Andean folding reaches Brazil only in the western part of Acre.

Important volcanic activity occurred in the Mesozoic. The basalt lavas extruded through numerous fissures (dikes) striking NW-SE. Local magmatic differentiation led to alkaline and ultrabasic volcanics. Post-Cretaceous basaltic lava flows occur in several places in northeastern Brazil, as well as in the oceanic islands of Fernando de Noronha and Trinidad.

(3) Precambrian

Precambrian rocks make up the cratonic areas and were emergent during most of subsequent geologic period. However, in restricted areas they have undergone negative movements due to faulting at various times (Figure 4-3).

Figure 4-3 Geologic Map of Brazil (based on Lamego: 1960)



The Precambrian shields were built up during several tectono-magmatic or orogenetic cycles or events which began in Archean times and were finished in the Early Paleozoic (Jequie, Transamazonian, Espinhaco-Uruacuano, Parguazan, Rondonian and Brazilian cycles or events). During the latest one cycle - the Brazilian or Brasiliano - all former Precambrian areas or smaller cratonic regions were consolidated tectonically into a broad and stable area - the Brazilian or South-American Platform.

The Archean (older than 2,600 m.y.) is normally represented by gneisses, migmatites, granites, granulites and mafic-ultramafics, however some proterozoic units may also be represented by these rocks. The extension of Archean rock-units in Brazil or even of some Proterozoic ones is not well defined. The difficulties are concerned to the isotopic rejuvenation or reworking by the overprinting of younger orogenic cycles or tectonomagmatic events. This overprinting which was developed mainly in Proterozoic times does not permit to define with precision the geocronologic age of large areas of the so called "crystalline complex" or "Precambrian basement" in Brazil. Also during the Archean and probably during the Early Proterozoic, narrow volcano-sedimentary sequences of greenstone belts or similar types were formed. Like other parts in the world the greenstone belts are important for the generation of many mineral deposits.

The Proterozoic (2,600 - 570 m.y.) in Brazil is characterized by hundreds of kilometers of long fold belts and correlated platform covers, made up by sedimentary rocks and volcanics, mainly of low or slight metamorphic grade, which in many cases are associated with granitic magmatism. The most important fold belts are of the Middle and Late Proterozoic: Espinhaco, Uruacu, Paraguai - Araguaia, Southeast, Northeast and Brasilia. Large areas in the states of Minas Gerais and Bahia and the Amazon region show platform covers, specially from the Middle Proterozoic (1,900 - 1,100 m.y.). In the Amazon area there are different granite forming events associated to such platform covers which are responsible for important tin mineralizations.

Supracrustal units of the Early Proterozoic (2,600 - 1,900 m.y.) do not form in Brazil large belts, but they are responsible for one of the highest iron concentrations in the world, like the Minas Supergroup in the Quadrilatero Ferrifero, Minas Gerais State and the Grao Para Group, in the Serra dos Carajas area. In Bahia State the Early Proterozoic Jacobina Supergroup bears gold conglomerates of the Witwatersrand type.

(4) Paleozoic

The Parnaiba, Sao Francisco, Parana and Amazon intracratonic basins subsided during the Lower Paleozoic. During the Paleozoic and Mesozoic, these basins were subjected to repeated periods of subsidence and sedimentation alternated with periods of emergence and erosion. The areas of these basins were about the same during both eras. The uplift was gentle without strong folding and only with slight epeirogenic warping. The slightly negative tendency of the basins has become reduced in more recent times. The basins were mostly marine in the Lower Paleozoic, becoming continental in the Upper Paleozoic.

In the Amazon Basin, the first well-established Paleozoic sequences are marine Ordovician as indicated by the brachiopod Orthis callactis. Most of the Precambrian areas at the beginning of the Devonian were a peneplain, probably formed under humid climatic conditions. The Devonian sea transgressed this erosion surface leaving thick deposits of cross-bedded sandstone and fossiliferous shale. In the Amazon Basin, Protosalvinia brasiliensis is a typical fossil plant.

The sea then retreated, and the land was eroded for a long period of time. This was the "Gondwana" cycle of erosion, widely recognized in the southern hemisphere. In the Parana Basin the Gondwana facies may be called the Santa Catarina "Supergroup."

(5) Mesozoic

Most of Brazil was above sea level during the Mesozoic. Only in the Cretaceous did the sea invade several areas in the north and northeast.

The Triassic sediments are continental and were deposited in an arid environment. The sedimentation was very extensive in the Parana and Parnaiba basins, and seas transgressed far over the shield areas. It is overlain by the Botucatu Formation, formed under arid conditions and representing one of the largest fossil desert environments in the world. Much volcanic activity occurred in the Rhaetic and covered the Parana Basin with several thick basaltic lava flows (1,560 m in Porto Epitacio, SP). The total area of lava flows is about 1,200,000 km^2, the largest in the world. Volcanism occurred also in northern Brazil (Roraima) and in the Parnaiba Basin. During and after the lava flows, arid conditions prevailed in the Parana Basin.

From an economic and petroleum exploration point of view, the Cretaceous coastal, marginal, taphrogeosynclinal basins are very important. They date from the separation of the South American continent, which began in the Lower Cretaceous (130 m.y) and initiated the opening of the South Atlantic. The correlation of the sediments of these basins with their counterparts on the African margin has now been well established.

All of the contemporary petroleum production are derived from these marginal basins. The Campos, Reconcavo, Sergipe-Alagoas, Potiguar, Ceara and Espirito Santo basins are responsible for the whole oil and gas production in the country. Other basins are in phase of study or in phase of data reevaluation. The major supply at present comes from Rio de Janeiro's Campos Basin (offshore) and from Bahia's Reconcavo Basin (onshore). All sedimentary basins are being intensively explored, both on and offshore by Petrobras, the government-operated oil monopoly, and new strikes may be expected in the presently nonproducing basins.

Salt has been drilled or detected geophysically in most of the marginal basins north of Parana. These Cretaceous salt occurrences, besides offering excellent structural traps for oil, are the raw material for a developing chlorine and caustic soda industry in the state of Alagoas. Deposits in Sergipe of carnallite and sylvite, associated with the salt, are awaiting development.

(6) Cenozoic

Erosion was the main feature of the Cenozoic in Brazil. However, Cenozoic sediments cover large areas in Amazonia, Pantanal, the northern part of the Parnaiba Basin and parts of the coast as well as small basins such as the Curitiba, Sao Paulo, Gandarela, and Itaborai. Many of the Cenozoic sediments were deposited under semi-arid conditions during the development of peneplain surfaces. Faulting or deep-seated folding were responsible for small steep tectonic basins and for larger shallow and flat basins.

The Barreiras Series, considered Pliocene, is the most important Cenozoic sequence in Brazil. It is present in the Amazon Valley and contains Dinosuchus terror, an enormous fossil crocodile about 10 m long.

(7) Sedimentary History

In summary, the sedimentary history of Brazil can be subdivided into five sequences of deposition with corresponding interruptions marked by regional unconformities:

(a) Erosion interval of regional extent but inadequately known:

Ordovician to early Carboniferous deposition

(b) Middle Carboniferous (Namurian), unconformity of regional extent:

Late Carboniferous to Permian (Gondwana) depositional phase

(c) Triassic and a large part of Jurassic, interval of erosion:

Lower Cretaceous (Wealdian) depositional phase - a wide swath of sediments deposited northward of Bahia

(d) Post-Wealdian - Pre-Aptian unconformity - very extensive:

Aptian-Albian deposition - widespread over the eastern half of Brazil

(e) Upper Cretaceous-Tertiary unconformity:

Tertiary Deposition

In the intracratonic depressions there was extensive continental deposition during marine regressions. During the Cenozoic, a cyclic alternation between semi-arid and humid conditions is evident, as well as an active epeirogenic uplift represented by several erosion levels. The tropical, humid phases were probably very warm, while the semi-arid conditions were most likely cooler.

Table 4-1 Geological Column of the Greater Carajas Program Area

Era	Period					
Era	Period	Cráton Amazónico / Faixa Araguaia / Cráton de São Luis				
Cenozoic	Quaternary		Alluvium	Qal	---	clay, sand, gravel
Cenozoic	Tertiary		Detrital deposits	TQc	—	detrital deposits, laterite
Cenozoic	Tertiary		Barreiras G.	Tb	—	fine grained sandstone, siltstone and mudstone containing lenticular conglomerate and coarse grained sandstone
Mesozoic	Cretaceous		Alter do Chão F.	KTac	—	greywacke, sandstone and mudstone
Mesozoic	Cretaceous		Itapecuru F.	Ki	200-600m	red sandstone and mudstone
Mesozoic	Cretaceous		Codó F. / Grajaú F.	Kc / Kg	20-180 (Kc) m	Kc ; mudstone, limestone, gypsum and fine grained sandstone Kg ; medium grained sandstone and mudstone
Mesozoic	Cretaceous		Sardinha F.	Ks	5-200m	dark grey amigdaloidal basalt
Mesozoic	Jurassic		Corda F.	Jc	8-25m	red and purple sandstone (fine and medium grained) containing fossiliferous mudstone and basal conglomerate
Mesozoic	Jurassic		Pastos Bons F.	Jpb	30-65m	rosy and green mudstone and fine to medium grained sandstone, interbedded with grey mudstone containing fossils locally
Mesozoic	Triassic		Mosquito F.	TRJm	4-175m	dark grey to black aphanitic basalt, interbedded with whitish fine to medium grained sandstone
Mesozoic	Triassic		Sambaíba F.	TRs	—	rosy to whitish, fine to medium grained sandstone
Paleozoic	Permian		Motuca F.	PTRm	100-160m	red fine to medium grained sandstone, interbedded with siltstone and red mudstone
Paleozoic	Permian		Pedra de Fogo F.	Ppf	50-170m	rosy fine to medium grained sandstone, red and violet siltstone and mudstone
Paleozoic	Carboniferous		Piauí F.	Cpi	50-300m	rosy and whitish medium grained sandstone, siltstone and red mudstone
Paleozoic	Carboniferous		Poti F.	Cpo	50-200m	rosy and whitish fine to medium grained sandstone, interbeded with siltstone and mudstone showing purplish grey and red color
Paleozoic	Carboniferous / Devonian		Longá F.	DCl	60-120m	dark grey and purple mudstone and siltstone, and fine grained sandstone
Paleozoic	Devonian		Cabeças F.	Dc	100-300m	whitish fine to medium grained sandstone
Paleozoic	Devonian		Pimenteiras F.	Dp	80-200m	alternating beds of creamy and greenish fine grained sandstone, siltstone, grey and purple mudstone, containing ferruginous or calcareous oolite bed
Paleozoic	Cambrian	Cráton de São Luis	Piriá F.	PPp		subarkosic fine grained sandstone, mudstone
Paleozoic	Cambrian	Cráton de São Luis	Viseu F. / Igarapé de Areia F.	PPv / PPi		arkose sandstone conglomerate
Proterozoic	Late	Cráton Amazónico	Suite Intrusiva Redenção	PSγr	—	rapakivi granite and granophyre
Proterozoic	Late	Cráton de São Luis	Alcalina Boca Nova	PSλ		nepheline graisse
Proterozoic	Late	Cráton de São Luis	Granitic rocks	PSγ	—	
Proterozoic	Late	Cráton de São Luis	Gurupi F.	PSg		meta-sandstone, philite, meta-greywacke, interbeded with quartzite
Proterozoic	Middle	Cráton Amazónico	Cubencranquém F. / Triunfo F.	PMc / PMt		subarkosic and sublithic sandstone, arkosic sandstone, pyroclastics, lithic sandstone, greywacke, vitric tuff, chert, volcanic breccia
Proterozoic	Middle	Cráton Amazónico	Suite Intrusiva Tarumã	PMγt	—	biotite granite, monzonite, alkali-granite, hornblende-biotite granite, granodiorite, tonalite
Proterozoic	Middle	Cráton Amazónico	Gorotire F.	PMg		orthoquartzitic sandstone, feldspathic and sublithic sandstone, arkose, greywacke, conglomerate
Proterozoic	Middle	Cráton Amazónico	Suite Intrusiva Rio Dourado	PMγrd	—	granite, granophyre, porphyritic granite, graphic granite,
Proterozoic	Middle	Cráton Amazónico	Uatumã G. – Sobreiro F.	PMus		porphyritic andesite, porphyrite, augite-hornblende andesite
Proterozoic	Middle	Cráton Amazónico	Uatumã G. – Iriri F.	PMui		dacite, rhyolite, rhyodacite, andesite, pyroclastics, rhyodacitic crystalline tuff, vitric tuff, dacitic meta tuff, tuffaceous sandstone, (t) means tuff
Proterozoic	Middle	Cráton Amazónico	Velho Guilherme Granite	PMγv	—	granite, granodiorite
Proterozoic	Middle	Cráton Amazónico	Serra dos Carajás Granite	PMγc	—	porphyritic granite, granodiorite
Proterozoic	Middle	Faixa Araguaia	Tocantins G.	PMt (ν)		fillite, chlorite schist, metaarkose, metagreywacke, quartzite, jasper, marble, (ν) means ultrabasic rocks
Proterozoic	Middle	Faixa Araguaia	Estrondo G.	PMe		quartz-feldspathic schist, amphibole schist, migmatite, gneiss, ferrgineous quartzite, orthoquartzite, metaconglomerate
Proterozoic	Early	Cráton Amazónico	Rio Fresco F.	PIrf		conglomerate, sandstone, siltstone, mudstone, containing calcareous bed and basic volcanic bed
Proterozoic	Early	Cráton de São Luis	Tromaí F.	PIγat		granitic rocks, andesite, rhyolite
Proterozoic	Early	Cráton de São Luis	Granitic rocks	PIγ	---	
Proterozoic	Early	Cráton de São Luis	Santa Luzia F.	PIsl		schist complex, garnet-biotite schist, gneiss, quartzite, marble, leptinite, amphibolite, mafic rocks
Proterozoic / Arquean		Cráton Amazónico	Granitic rocks	APIγ	—	
Arquean		Cráton Amazónico	Grão Pará G.	Agp		mafic metavolcanic rocks, itabirite gneiss, schist (amphibole-garnet-magnetite-copper sulphide), quartzite, amphibole schist, metabasalt, anthophyllite-cordierite rock
Arquean		Cráton Amazónico	Xingu Complex	Ax		gneiss, amphibolite, granite, migmatite (μ), granulite (ɣ), greenstone belts/granitic rock (d), basic-ultrabasic complex (β)
Arquean		Faixa Araguaia	Colméia Complex	Ac		migmatite, granite, quartz-feldspathic schist, basic schist and amphibolite
Arquean		Cráton de São Luis		A		granitic rocks, gneiss having granitic composition, leptinite, mafic to ultramafic rocks, granulite, charnockite, anorthosite

Table 4-2 Stratigraphic Correlation of the Greater Carajas Program Area

GEOLOGICAL AGE		GEOLOGIC MAP OF BRAZIL (DNPM 1981) 1/2,500,000 REGION II	REGION III	REGION V	PROJETO RADAMBRAZIL SC - 22 (1975) 1/1,000,000	PROJETO RADAMBRAZIL VOL. 4 SB/SC - 22 (1974) 1/1,000,000	Abreu, F.M.de; Villas, R.N.N.; Hasui, Y. (1980)	Costa, J.B.S. (1980)	Ianhez, A.C.; Souza, A.M.S.de; Montalvão, R.M.G.de (1980)	PROJETO ESTUDIO GLORAL DOS RECURSOS MINERAIS DA BACIA SEDIMENTAR DO PARANAIBA (DNPM/CPRM 1978)	RADAMBRAZIL VOL 22 SC - 22 (1981)	PROJETO MAPA DE PREVISÃO DA PROVINCIA ESTANÍFERA DO SUL DO PARÁ (DNPH 1973)	GEOLOGIA REGEONAL DA PROVINCÍA MINERAL DE CARAJÁS (DOCEGEO 1982)	PROJETO INTEGRACAO GEOLOGICO - GEOFISICA SUL DO PARA (DNPM/CPRM 1979)
PHANEROZOIC CENOZOIC QUATERNARY	HOLOCENE		QH		QH	Qa				Qal alluvides				
	PLEISTOCENE		QP		QP									
TERTIARY	NEOGENE PALEOGENE		TT, TTb			Tb Barreiras F.				TQc Cobertura Tp Pirabas				
MESOZOIC	CRETACEOUS		Kit Kcg Kcp			Ki Itapicuru F.				Ki Itapecuru Kc Codo } Kg Grajáu Ks Sardinha				
	JURASSIC		Jβm Js			JKo Orozimbo F.				Jc Corda Jpb Patos Bons TRJm Mosquito				
	TRIASSIC					TRs Sambaiba F.				TRs Sambaiba PTRm Matuca				
PALEOZOIC	PERMIAN		Ppf		Ppf Pedra de Fogo F.	Ppf Pedra de Fogo F.		Pedra de Fogo F. (Ppf)		Ppf Pedra de Fogo				
	CARBONIFEROUS		Cpi Cp		C Piaui and Poti F.	Cp Piaui F				Cpi Piaui Cpo Poti				
	DEVONIAN		Dl Dcb Dp (SDsg)	SOrb	Dl Longá F. Dc Cabeças F. Dp Pimenteiras F SDsg Serra Grande F.	Dl Longá F Dp Pimenteiras F.		Pimenteiras F (Dp)		Dcl Longá Dc Cabeças Dp Pimenteiras SDsg Serra Grande	SDsg Serra Grande F.			
	SILURIAN					(St) Trombetas F								Stb Trombetas F
	ORDOVICIAN													
	CAMBRIAN		PPp	PPmc	Cap? Alto Paraguai G.		Ep Piriá F				pCdi Diamantino F			
PROTEROZOIC	LATE		PSγ PSg	PSγ (PSb)	Tocantins G. pCAl pCA(xq)		Fv Fia Vizeu F Igarape de Areia F Gγ CT Gurupi F Chega Tudo F.	Rio dos Barreiras F. (Op) Granito intrusive	Basic intrusive		pCγr Pedenção Granite (585±39)			pCpp Prosperança F
	MIDDLE	PMc PMγv PMg PMTc PMαi	PROTEROZOIC UNITS GENERATED IN OR REWORKED DURING BRAZILIAN CYCLE PsI	PMt PMel PMγ	pCBg.c Gorotire and Cubencranquem F. pCBγv Granito Velho Guilherme pCBαi Uatumã G.: Iriri F. pCCgp Grão Pará G.	pCtf Triunfo F. pCgo Gorotire F. pCγv (±1,380) Granito Velho Guilherme Uatumã G: pCai Iriri F.; pCse Sobreiro F.; pCγc G. da Serra dos Carajás (±1,700); pCrn pCra Rio Fresco F. {Naja M. Azul M.	Eγ Tromaí F SL São Luiz F.	Tocantins G { Pequizeiro F (PMt) Estrondo G {Canto da Vazante F, Xambioá F., Morro do Campo F (PMet)	Granito intrusive (PMγc) (PCγv) Gorotite F (PMg)	Basement	ptc Cubencranquem F pCγt Tarumã Granito (1,541±22) pCgo Gorotire F pCγrd Rio Dourado Granite (1,737±50) pCai Iriri F. (1,355±29) pCβγq G pCt Tocantins G pCe Estrondo G	pCtf Triunfo F. pCgo Gorotire F pCγvg Granito Velho Guilherme pCCir Iriri F pCEs Sobreiro F. pCCgd Granito Serra dos Carajás pCrf Rio Fresco F pCt Tocantins G pCax Araxá G	pCt Tocantins G pCe Estrondo G go Gorotire F grvg Granito Velho Guilherme Vu Iriri F Vu Sobreiro F grsc Granito Serra de Carajás rf Rio Fresco F	pCtc Tocantins G pCc Cubencranquem F pCγp Tres Pires intrusive pCir Iriri F. pCgo Gorotire F
	EARLY	Ptrf Plgn APIγ	PIγα PIγ			pCgp Grão Pará G. pCt (±2,000) Tocantins G. pCa Araxá G.			Serra do Inajá G (Agp) {Metasedi-ferrifera F, Metavul acida, Metamaficas, Metaultramaficas		pCsi Serra do Inajá G.	pCgpa Grão Pará G	gp Grão Pará G ms Salobo-Pojuca Sequence	pCgp Grão Pará G pCjr Granito Juruena
ARCHEAN		Agp γβ A(T)x μ Ac η	A(T-B)		pCγ Xingu Complex	pCx Xingu Complex	CM Maracaçumé Complex (A(T-B))	Colmeia Complex (PMet)	Xingu Complex (A(T)x)		pCx Xingu Complex (2,596±79)	pCxg Xingu Complex	grgn gb Xingu Complex with (greenst belt)	pCx Xingu Complex

4-2 Geology of the Greater Carajas Program Area

4-2-1 An Outline of the Geology

The geology of the Greater Carajas Program Area (the PGC Area) consists of all strata of the Precambrian Archean - Cenozoic. A border line, longitude 48° west, divides the geology into the western area of Precambrian and the eastern area of post-Precambrian.

The former consists of metamorphic rocks, sedimentary rocks and igneous rocks of Archean and Proterozoic. The principal part comprises part of the Tapajos Craton and is distributed to the west of longitude 48° west and to the south of latitude 3° south. Metamorphoric rocks and igneous rocks are also distributed in and around the mouth of Rio Gurupi in the northern area of the state of Maranhao on a small scale.

The latter mainly consists of sedimentary rocks, distributed widely to the east of longitude 48° west and forms the Maranhao Basin. The similar sedimentary rocks are distributed along Rio Amazonas in the north of latitude 3° south and the west of longitude 48° west, forming the eastern part of the Amazon Basin.

The geological structure of Precambrian basement rocks prevails in the direction of WNW-ESE, besides which faults and folds of NE-SW and N-S systems are recognized. Synclinal structures develop obviously in the mountain ranges of Serra dos Carajas, Serra da Tocandera, Serra dos Gradaus and Serra das Andorinhas. The Araguaia-Tocantins orogenic belt develops along two rivers, Rio Tocantins and Rio Araguaia in the direction of north-south. The orogenic belt divides the geology into the post-Precambrian geology of the eastern Maranhao-Piaui Basin area and the Precambrian geology to the west fairly obviously.

As to the post-Precambrian geology, the basin structure (Maranhao-Piaui Basin) to the north and the syncline structure (in the eastern edge of the Amazon Basin) that develops along the Rio Amazonas drainage in the direction of ENE-WSE are featured. Plate III-2 shows a geological map of the area at a scale of 1:1,000,000. Table 4-1 shows a geological column and Table 4-2 shows a stratigraphical correlation table.

4-2-2 Stratigraphy

The geology of the PGC Area exhibits many differences in the western and eastern areas of longitude 48° west. The stratigraphical division of each area is described as follows:

(1) Stratigraphy of the West of Longitude 48° west

(a) Precambrian Geology

(a-1) Xingu Complex (Ax) and Colmeia Complex (Ac)

Xingu Complex (Ax) forms the basement of the area and is widely distributed to the west of Rio Tocantins and Rio Araguaia. The principal rocks consist of gneiss, biotite schist, migmatite granite, granulite, amphibolite, metabasite, ultramafic rocks, cataclastic rocks and milonite which belongs to polimetamorphic rocks of green schist-granulite facies. DOCEGEO describes that the so-called "Greenstone Belt," consisting of basic rocks of a low metamorphoric grade, is included within the Xingu Complex. These rock facies are similar to those of Grao Para Group.

Colmeia Complex (Ac) is distributed in the area between Rio Tocantins and Rio Araguaia on a small scale. The principal rocks consist mainly of granite, gneiss and migmatite. The Xingu Complex and the Colmeia Complex are penetrated by granite (1,800 - 2,000 m.y.) and are substanced by Trasamazonas orogenic movements.

(a-2) Grao Para Group (Agp)

Grao Para Group is distributed in the mountain ranges of Serra dos Gradaus, Serra das Andorinhas and Serra do Inaja. It is also widely distributed in and around Serra dos Carajas, overlying the Xingu Complex unconformably. The principal rocks consist mainly of gneiss, schist, amphibolite, metabasalt, quartzite, chert, and iron formations of green schist-amphibolite facies. In general, basic volcanic rocks and basic metamorphic rocks develop in the lower part, while iron formations develop in the upper part of the group.

The Salobo ore deposit (Cu) and the Pojuca ore deposit (Cu-Zn) are embedded in amphibolite, gneiss and quartzite in the lower part of the group while iron ore deposits in Carajas are embedded in the upper part.

DOCEGEO has described a sequence in which Cu and Cu-Zn ore deposits are divided independently of the group, and has called it the "Salobo-Pojuca Sequence." In addition, iron formations in which itabilite dominates have been called the "Carajas Formation." According to DOCEGEO, the basic volcanic rocks and amphibolite distributed in the southern part of Serra dos Carajas have been classified as "Greenstone Belt" which is intercalated in the Xingu Complex. However, they have been classified into the Grao Para Group in the geological maps of RADAMBRASIL VOL. 22 (1981) and DNPM (1982). In this report, DNPM's classification is mainly adopted from the viewpoint of regional geology.

(a-3) Rio Fresco Formation (PIrf)

It is distributed along the synclinal structures of Serra dos Carajas, Serra dos Gradaus, Serra das Andorinhas and Serra Pelada, overlying the Grao Para Group unconformably. The principal rocks consist mainly of thick sedimentary rocks such as conglomerate, sandstone, siltstone and shale, and basic volcanic rocks partially intercalates. Coarse grained rocks generally dominate in the lower part, while fine grained rocks and intercalating chert are predominant in the upper part.

In Serra dos Gradaus, fine grained matters are predominant and a carbonate stratum is often intercalated. Lignite beds are intercalated in part of sandstone beds and manganese gossans are partly recognized in fine grained sediment and chert. In Serra Pelada, gold ores are embedded in siltstone and shale. In particular, gold is concentrated in the areas where folding and faulting structures are predominant.

In Serra Norte of Serra dos Carajas, Azul manganese deposits are embedded in calcareous siltstone. Some manganese ore deposits are also known in Serra do Sereno and Serra do Buritirama. In Serra das Andorinhas, lead-silver gossans are embedded in chert or calcareous shale.

(a-4) Uatuma Group

It consists of two formations known as Sobreiro Formation (PM s) and Iriri Formation (PMαi). Non-metamorphozed and non-folded volcanic rocks are featured and are predominant in Rio Xingu, Rio Iriri and Rio Fresco. Sobreiro Formation (PMαs), named by IDESP in 1972, refers to the unit of intermediate rocks distributed in the Rio Fresco Basin. The principal rock facies consists of andesitic porphyry, porphyritic andesite, and augite-hornblend andesite. Iriri Formation (PMαi), named by GEOMINERAÇAO/SUDAM in 1972, refers to the unit of felsic rocks distributed widely in Rio Xingu and Rio Iriri. The principal rock facies consist of dacite, rhyolite, rhyodacite, andesite, volcanic pyroclastics and ignimbrites. While the Sobreiro Formation and the Iriri Formation are characterized by intermediate and/or felsitic, continental volcanic rocks, showing interfinger relationship, the former is assumed to be located in the lower part.

(a-5) Gorotire Formation (PMg)

Gorotire Formation is distributed in Serra do Gorotire, unconformably overlying the Iriri Formation. Besides, it is also scatteredly distributed in the upstream of Rio Fresco and in Serra do Inaja. The principal rocks consist of feldspathic sandstone, conglomerate siltstone and mudstone.

(a-6) Cubencranquem Formation (PMr)/Triunfo Formation (PMtf)

They are distributed in Serra do Cubencranquem and Igarape Triunfo, unconformably overlying the Gorotire Formation on a small scale. The principal rocks are composed of sub-arkosic, sub-lithic sandstone, volcano-clastic arkosic sandstone, lithic sandstone, lithic-vitric graywake, vitric tuff, banded chert and volcanic breccia.

(a-7) Granite Intrusion

(i) Serra dos Carajas Granite (PMγC)

It is distributed in and around Serra dos Carajas and Serra dos Gradaus forming a circle of 25-65 km in diameter and intruding into the Rio Fresco Formation. The principal rock facies varies from granitic to grano-dioritic and generally includes biotite and sometimes accompanies quartz-feldspar veins, pegmatite and tourmaline. Geologic time of the granite is estimated at 1,600-1,800 m.y. The granite rocks are associated with Au mineralization.

(ii) Velho Guilherme Granite (PMγv)

It is distributed in and around Velho Guilherme and Sao Felix do Xingu, and constitutes a circular shaped stock body of 5-15 km in diameter, intruding into the Iriri Formation. Rock facies are variable from granitic to grano-dioritic facies, and show sub-volcanic characteristics and generally include biotite.

The rock facies of the Velho Guilherme type granite generally contains cassiterite in greisen zones associated with topaz and fluorite. Sn ore deposits such as those in Velho Guilherme, Antonio Vicente and Mocambo are all associated with this type of rocks. Geologic time of the granite is estimated at 1,300-1,400 m.y.

(iii) Rio Dourado Intrusive (PMγrd), Taruma Intrusive (PMγc) and Redencao Intrusive (PSγr)

The intrusive rocks distributed to the south of latitude 8° south and to the west of longitude 50° west are classified on the basis of geochronological results of PROJETO RADAMBRASIL Vol. 22 (DNPM: 1981) as follows:

Rio Dourado Intrusive	1,737 ± 50 m.y.
Taruma Intrusive	1,641 ± 22 m.y.
Redencao Intrusive	685 ± 38 m.y.

Rio Dourado Intrusive shows rock facies of granite, granophyre, and porphyritic granite with characteristics of rapakivi texture. It is a subvolcanic-plutonic intrusive rock related to volcanic activities. The above geochronological classification corresponds to that of Serra dos Carajas Granite while the scale, features and rock facies of the intrusive body are similar to those of Velho Guilherme Granite.

Taruma Intrusive is distributed in and around Serra do Inaja on a small scale, showing rock facies of biotite, granite, monzonite, alkali granite, biotite-hornblend granite, granodiorite and tonalite. Redencao Intrusive is distributed in the northern part of Serra do Inaja, showing rock facies of rapakivi granite and granophyry.

(a-8) Estrondo Group (PMe)/Tocantins Group (PMt)

They are distributed along Rio Tocantins and Rio Araguaia, constituting the so-called Araguaia-Tocantins Orogenic Belt (RADAMBRASIL: 1974). The Orogenic Belt is situated between the Tapajos Craton basement and the Maranhao-Piaui Basin and stretches in the direction of north-south at a width of 100-150 km.

The geology and geological structure of the PGC Area show many differences on both sides of the Orogenic Belt. Metamorphic rocks and sedimentary rocks are the principal rock facies of those groups; however, Estrondo Group has a higher metamorphic grade than Tocantins Group.

(i) Estrondo Group (PMe)

Estrondo Group is narrowly stretched in a north-south direction along the eastern side of Rio Araguaia. The principal rock consists mainly of feldspar-quartz schist, amphibole schist, migmatite, quartz-feldspar-biotite-muscovite gneiss, ferrugenous quartzite, ortho-quartzite and meta-conglomerate. The grade of metamorphism is variable from green schist facies (biotite zone) to amphibolite facies (staurolite zone), and it is generally lower in the west.

(ii) Tocantins Group (PMt)

Tocantins Group is distributed along Rio Tocantins and Rio Araguaia in the direction of north-south. The principal rocks are consisted of phyllite, schist, meta-graywake, quartzite, jasper, marble, meta-siltstone and meta-argillite. These rocks are weakly metamorphosed and form, for instance, green schist facies/(chlorite zone). Basic-ultrabasic rocks (u) and stock-dykes are formed in the direction of north-south and intrude into this rock group with frequent association with Ni mineralization.

The stratigraphical situations of these groups have been frequently studied in the past; however, it is difficult to determine their relationship with the Xingu Complex and other strata because there is little evidence to indicate a direct contact between them. It is reported that a reverse fault develops from Rio Vermelho to Rio Tocantins, and that the Tocantins Group overlies the Xingu Complex (Almeida and Hasui 1980).

The results of geochronological studies indicate too wide a variation from 650 m.y. to 2,000 m.y. to obtain reliable values. Presumably, the wide variation is due to differing sampling and measurement methods and metamorphic influences.

In this report, these groups are considered stratigraphically younger than the Xingu Complex and the Rio Fresco Formation that are subject to tectonic control of a WNW-ESE system.

(b) Post-Precambrian Stratigraphy

A synclinal structure develops in the direction of ENE-WSW along the downstreams of Rio Xingu and Rio Amazonas. Ordovician-Jurassic sediments are distributed in small and narrow areas in and around Altamira of Rio Xingu and, in the north, Cretaceous and Quaternary sediments stratigraphically overlie the former.

(b-1) Ordovician - Silurian (OSt)

It is distributed in the N60-70E strike from the Joao Ribeiro stream or the Transamazon highway to Volta Grande do Xingu to the east of Altamira, and directly overlies the Xingu Complex unconformably. The principal rocks consist of sandstone, orthoquartzite, conglomerate, siltstone, shale and so forth, and coarse grained sediment is dominant in the lower part.

(b-2) Devonian (Dc, Dm)

It overlies lower formations conformably in a narrow area from the Transamazon highway to Rio Xingu. Generally, it strikes N60-70E, and dips moderately towards the north or NNW. The principal rock facies consists mainly of well-bedded fine grained sedimentary rocks, such as fine micaceous sandstone, micaceous siltstone and shale.

(b-3) Jurassic (JBp)

It is distributed along the Transamazon highway in the north of Altamira, overlying lower formations unconformably. The principal rock consist of diabase as a product of a basic volcanic activity of the Jurassic-Cretaceous period. According to Basei (1973), geologic time of Jurassic sediment is estimated at 134-175 m.y., which is consistent with the Jurassic-Cretaceous period.

(b-4) Cretaceous (KTac, Kc, Ki)

It is distributed widely in and around Rio Xingu and Rio Amazonas, overlying lower formations unconformably. The principal rock consists of fine grained red-sandstone, and interbedded siltstone or thin shale beds in the lower part.

(b-5) Quaternary (Qal)

It is distributed in Rio Amazonas, the Rio Para estuary, Marajo Island and along major rivers. The principal sediment is unconsolidated alluvial sediment, accumulated in the estuaries of Rio Amazonas and Rio Tocantins.

(2) Stratigraphy of the East of Longitude 48° West

The Precambrian geology is distributed on a small scale along Sao Luis - Rio Gurupi in the northeast part of the area. The post-Precambrian geology has a large exposure forming the Maranhao-Piaui Basin.

(a) Precambrian Geology

(a-1) Maracacume Complex (A)

It is distributed in the mouth of Rio Gurupi trending in the direction of NW-SE, and constitutes the basement of the area just as the Xingu Complex. The principal rocks consist of granite, granitic gneiss, leptinite, mafic and ultramafic rocks, granulite, charnockite and anorthosite.

(a-2) Santa Luzia Formation (PIsl)

It is distributed in the downstream of Rio Gurupi in the direction of NW-SE, and overlies the Maracacume Complex unconformably. Abreu and Hasui (1980) consider, however, that it should be generally classified into "Gurupi Formation" (see item "a-4" below). The principal rocks consist of biotite schist, muscovite schist, garnet schist, gneiss, amphibolite and mafic rocks belonging to green schist-amphibolite facies.

(a-3) Tromai Formation (PIγαt)

It is distributed in the area from the mouth of Rio Gurupi to the mouth of the Rio Turiacu, through Rio Tromai, trending in the direction of NW-SE. The principal rocks consist of hypabyssal rocks and volcanic effusive rocks. Granodiorite, granite, tonalite, trondhjemite, quartz-andesite, dacite, rhyolite and tuff are exposed. The grade of metamorphism and fold structure of the formation have not been made clear yet.

(a-4) Gurupi Formation (PSg)

It is distributed along the north side of the Santa Luiza Formation, from Rio Caete to Rio Gurupi in the direction of NW-SE. According to Abreu and Hasui (1980), the formation is distinguished from the Santa Luiza Formation (a-2) and contacts with the latter by faults. The principal rocks consist of phyllite, meta-graywake and quartzite belonging to green schist facies.

(b) Post-Precambrian Stratigraphy

The Devonian-Jurassic formations are widely distributed along Rio Tocantins and Rio Parnaiba, and the Cretaceous formations in the area from the eastern side of Maraba to the downstream of Rio Parnaiba. The Tertiary formations are mainly spread to the south of

Belem; however, it is also distributed to the east of Sao Luis and other areas. The Quaternary formations, mainly alluvial deposits, are distributed in rivers and in the vicinity of Sao Luis.

(b-1) Devonian (Dp, Dc, Dcl)

It is divided into three formations in ascending order as follows:

Pimenteiras Formation	(Dp)
Cabecas Formation	(Dc)
Longa Formation	(Dcl)

Pimenteiras Formation (Dp) is distributed in the area from the confluences of Rio Tocantins and Rio Araguaia to the vicinity of Colinas de Goias, overlying the Colmeia Group unconformably. The principal rocks consist of siltstone, ferrugenous siltstone, argillite, sandstone and conglomorate.

Cabecas Formation (Dc) is scatteredly distributed around Colinas de Goias on a small scale, conformably overlying lower layers. The principal rocks consist of fine to medium size sandstone, siltstone and argillite. Cross bedding is characteristic of this formation.

Longa Formation (Dcl) is distributed in and around Colinas de Goias on a small scale, overlying the Cabecas Formation conformably. The principal rocks consist of well-bedded shale and siltstone, and often contain interbedded argillitic sandstone.

(b-2) Carboniferous (Cpo. Cpi)

It is divided into two formations known as Poti Formation (Cpo) and Piaui Formation (Cpi). The former is distributed to the east of Colinas de Goias and Floriano. The principal rocks consist of fine to middle grained sandstone in which shale, red siltstone and, in some cases, the lens of conglomerate are interbedded.

The latter is distributed along the south rim of the Maranhao Basin, from the vicinity of Colinas de Goias to that of Teresina, and conformably overlies the former formation. The principal rocks consist of sandstone, red marl, shale and so forth. Chert and conglomerate are interbeded partially. Cross bedding is developed among the uppermost red sandstone.

(b-3) Permian (Ppf. PTRm)

It is divided into two formations known as Pedra de Fogo Formation (Ppf) and Motuca Formation (PTRm). The former is distributed along the south rim of the Maranhao-Piaui Basin, from the vicinity of Colinas de Goias to that of Teresina, and conformably overlies the Piaui Formation (see above item "b-2"). The principal rocks consist of fine to medium grained sandstone, reddish shale-siltstone whose slumping structure can often be observed, and interbedded limestone and silex.

The latter is scatteredly distributed in and around the former formation. The principal rocks consist of red sandstone and interbedded red argillic siltstone-shale. Part of the Motuca Formation is Triassic.

(b-4) Triassic (TRs TRjm)

It is divided into two formations known as Sambaiba Formation (TRs) and Mosquito Formation (TRjm). The former is distributed from the vicinity of Araguaina to that of Sao Domingo do Maranhao, trending in a E-W direction. The principal rocks consist of light grey and well-sorted fine to medium grained sandstone. The latter is distributed in a limited area from the west of Tocantinopolis to the south of Grajau. The principal rocks consist of dark green-black basalt as the products of basic volcanic activity of the late Triassic - Jurrassic. The fine-medium grained sandstone lenses of the Macapa layer are partially interbedded, and also the Sambaiba sandstone is partially intercalated within the basalt in the base.

(b-5) Jurassic (Jph. Jc)

It is divided into two formations known as Pastos Bons Formation (Jph) and Corda Formation (Jc). The former is distributed in and around Colinas de Goias, to the southeast of the surveyed area, unconformably overlying lower formations on a small scale. The principal rocks consist of fine to medium grained sandstone-mudstone and grey shale, partially bearing fossils. The latter is distributed from the vicinity of Tocantinopolis to that of Teresina, unconformably overlying the Triassic geology discussed above. The principal rocks consist of red-purple fine to medium grained argillic sandstone containing fossils. Siltstone shale is partially interbedded.

(b-6) Cretaceous (Ks, Kc/Kg, Ki, KTac)

It is divided into three formations as follows:

Sardinha Formation (Ks)
Codo Formation (Kc)/Grajau Formation (Kg)
Itapecuru Formation (Ki)

These formations are widely distributed in the northern half of the Maranhao Basin. Sardinha Formation (Ks), as an inlier, is distributed only in the southern part of Barra do Corda on a small scale. The principal rocks consist of dark grey basalt with amigdaloidal texture.

As to Codo Formation (Kc) and Grajau Formation (Kg), the former

(Kc) is distributed in the vicinities of Imperatriz and Presidente Dutra on a small scale and consists of shale, limestone, gypsum and fine sandstone. The latter (Kg) is distributed in the direction of east-west, from the vicinity of Carajas to that of Sao Domingos do Maranhao, and consists of sandstone, shale and silex. Itapecuru Formation (Ki) is widely distributed in the center of the Maranhao-Piaui Basin. The principal rocks consist of reddish argillic sandstone, interbedding red siltstone and red argillite.

(b-7) Tertiary (Tb)

Barreiras Group (Tb) is widely distributed in the southern part of the Belem and Sao Luis areas on a small scale. The principal rocks consist of fine grained sandstone, siltstone and kaoline argillite and the lens of conglomerate and coarse grained sandstone are intercalated within them. Bauxite ore deposits in Paragominas are all embedded within the Tertiary rocks.

(b-8) Quaternary (TQc, Qal)

The former quaternary rock group (TQc) is distributed to the northwest of Fortaleza dos Nogueiras and in the south of the Maranhao Basin on a small scale, consisting of laterite and detritic materials. The latter group (Qal) is distributed in major rivers and around their estuaries, consisting of alluvial deposits of clay, sand, gravel and so forth.

4-2-3 *Geological Structure*

Geological structural provinces in the Greater Carajas Program Area (the PGC Area) are divided into the following three units:

(1) Tapajos Craton
(2) Araguaia-Tocantins Orogenic Belt
(3) Maranhao-Piaui Basin

(1) Tapajos Craton

It consists of Precambrian geology distributed widely to the west of Rio Tocantins and Rio Araguaia. Structural trends (foliation, fault, fold, etc.) of the crystalline rocks at the basement is predominantly NW-SE and tend to shift to WNW-ESE, dipping north. The predominant structural direction of meta-sedimentary rocks or volcanic rocks is WNW, which gradually shifts toward the north-west or east-west. The direction sometimes changes to the north-south or NE-SW and is partially affected by faults or intrusive rocks.

As a principal fold structure, synclinal structures are developed mainly in Serra dos Carajas, Serra da Tocandera, Serra das Andorinhas and Serra dos Gradaus. The syncline of Serra dos Carajas clearly shows a symmetric fold structure with both wings dipping north. The dip of sedimentary rocks ranges from 15 to 40 degrees, and the fold structure is invisible except in Serra Pelada. The typical synclinal structure is composed of meta-sedimentary rocks and meta-volcanic rocks of Grao Para Group and younger strata.

Fault structures are predominantly trending to the directions of NW-SE, WNW-ESE and NE-SW. In the non-metamorphosed sedimentary rocks, faults of north-west and east-west systems are developed. Along the contact between the eastern margin of basement crystalline rocks and the northern part of the Araguaia-Tocantins Orogenic Belt, a fault zone of N-S direction, dipping east, is developed, and a discontinuous line of principal structure is obviously distinguished in the Landsat images.

Faults in the Serra dos Carajas area are developed in the directions of NE-SW and NW-SE, although the former is predominant. The fault system developed in the area from western Serra dos Carajas to the north of Maraba, has been clearly recognized in the airborne magnetic and radiometric surveys. The fault indicates the characteristics of a right lateral fault, and it is assumed that the geology of Serra dos Carajas is dislocated northward by the fault and continues to the Bacaja area.

Granite is classified into two types: Serra dos Carajas Granite and Velho Guilherme Granite, clearly showing intrusion structure. The structure of surrounding host rocks shows a circular structure affected by the granite intrusion except Serra dos Carajas Granite. Dyke rocks, mainly basic rocks, intrude along the principal directions of the area in EW or NW. The dyke rocks are predominantly distributed in the Serra dos Carajas syncline and the Serra dos Gradaus syncline.

(2) Araguaia-Tocantins Orogenic Belt

The orogenic belt, stretching 1,200 km in the direction of north-south, is located between the Tapajos Craton and the Maranhao-Piaui Basin, and is overlain by younger formations in the north and eastern parts. At the western border of the belt, non-folded and folded rocks of the Tocantins Group are in contact with the Tapajos Craton by a fault known as "Tucurui Fault." In the vicinity of Rio Vermelho, an east-dipping reverse fault settles the Tocantins Group on the Xingu Group. The fault can be traced up to the Tucurui region, and forms a fault zone in the Tocantins Group to the north of Maraba.

Basement rocks are distributed in the vicinity of Xambioa, forming dome structures. Almeida and Hasui (1980) have classified the basement rocks into a rock group known as "Colmeia Group." Basic-ultrabasic intrusive rocks, stretching toward the directions of north-south and NW-SE are exposed in the vicinity of Rio Araguaia. Nickel and cromite ore deposits are embedded in parts of these rocks.

The geologic age of the Araguaia-Tocantins Orogenic Belt is assumed to be latter Uruacuanas (Almeida and Hasui 1980), and Schobbenhaus Filho et al. (1975a) and Hasui et al. (1980) have described that lineaments of Transbrasilian remain in the Belt.

(3) Maranhao-Piaui Basin

This geological unit stretches widely in the eastern half of the PGC Area. Paleozoic geology is distributed surrounding the southern half of the basin, and along the east side of the Araguaia-Tocantins Orogenic Belt in the direction of north-south, unconformably overlying the Estrondo Group (PMe). In the south and southeast of the basin, the general structural direction is E-W to NNE-SSW with a moderate dip. Mesozoic geology is widely distributed in the northern half of the basin, overlying the Paleozoic geology unconformably, and volcanic activity of the basalt can be recognized only in the center. Tertiary geology is distributed horizontally to the downstream of Rio Tocantins and Rio Capim, overlying the Mesozoic geology unconformably.

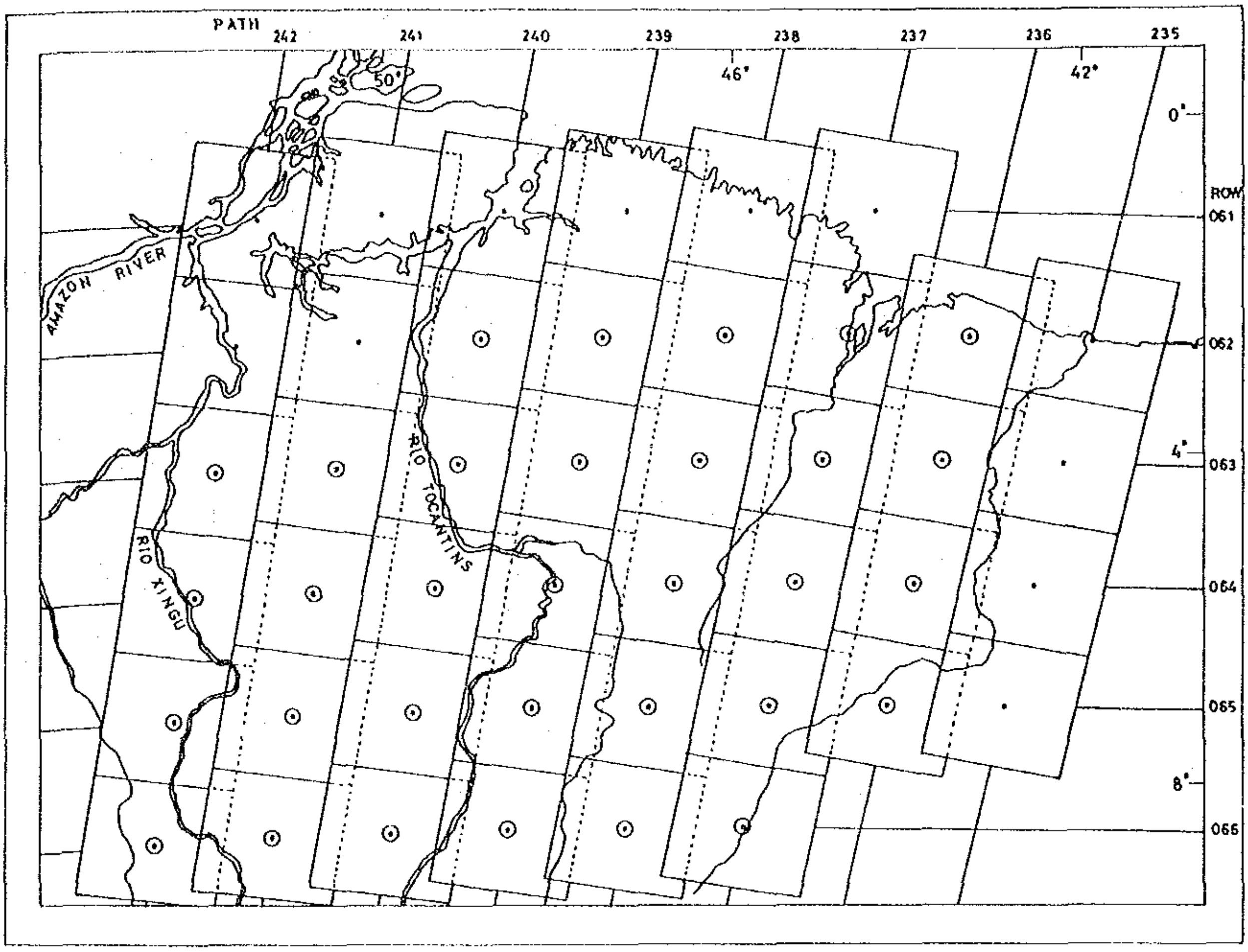
General faults in the basin are NE-SW and NW-SE systems. In the Rio Tocantins-Rio Araguaia area, however, a north-south system is predominant. The NE-SW and NW-SE system faults are developed in the basement area of Rio Gurupi.

4-3 Interpretation of Landsat Images

Interpretation of Landsat images was carried out for the entire area of the Greater Carajas Program. Although there are 44 scenes, only 32 scenes as shown in Figure 4-4 are actually interpreted because some scenes are widely covered by clouds. All the Landsat images have been checked as to their cloud coverage, locations of the clouds, and the quality of the data in Instituto de Pesquisas Espaciais (INPE) and the best data from each scene have been selected (see Appendices for a list of the data used).

The interpretation was conducted on 7-band black/white images which exhibit clear terrains in the dense vegetation, rather than other black/white images. Color composite images, or 5-band images were also used for some areas where known mineral deposits are located. The Landsat images were photogeologically interpreted to classify the geology of the area by discriminating the characteristics of resistance, drainage pattern, drainage density, tone, bedding, joint, vegetation and so on.

Figure 4-4 Landsat Coverage Index



⊙--- Landsat scenes from which data have been obtained

4-3-1 Results of Interpretation

Results of the interpretation have been compiled in a geological map at a scale of 1:1,000,000 (Plate III-2), and a detailed interpretation map has been prepared for the Inaja and Serra dos Gradaus areas in particular (Figure 4-5). The image characteristics of each formation are as follows:

(1) Xingu Complex (Ax)/Colmeia Complex (Ac)

The complex has a very low resistance and shows a low relief and very smooth texture. It also exhibits a fine dendritic drainage pattern.

(2) Grao Para Group (Agp)

Grao Para Group can be discriminated by its moderate to high resistance, low drainage density and grey to light tone on the 7-band images. Bedded structures are also observed in some areas.

(3) Rio Fresco Formation(PIrf)

This formation shows a low resistance and is more smooth in texture than the Xingu Complex. It appears from the images that the Rio Fresco Formation conformably overlies the Grao Para Group. The Rio Fresco Formation exposed in Serra dos Carajas, which forms a synclinal structure with the Grao Para Group, exhibits high resistance because it thinly overlies the latter which forms a resistant topography (plateau) in itself.

(4) Uatuma Group

(a) Sobreiro Formation (PMs)

The formation shows a low resistance which, however, is slightly higher than that of the Xingu Complex. The drainage is dense and has a dendritic pattern.

(b) Iriri Formation (PMαi)

It exhibits a moderate to high resistance and uneven topography. The formation forms a similar terrain to that of granitic rocks in the area; however, it can be differentiated from the latter because of the existence of bedded structures.

(5) Gorotire Formation (PMg)

The formation shows a very dark tone on the 7-band images because of sparse vegetation. It exhibits a moderate resistance and forms even topography. Lineaments are predominant in this formation exposed to the south of Rio Fresco, and this is ascribed to basic dikes.

(6) Cubencranquem Formation (PMc) and Triunfo Formation (PMtf)

The characteristics of these formations are the same as those of the Gorotire Formation, hence it is very difficult to differentiate them from the latter.

(7) Estrondo Group (PMe)

The group shows a low to moderate resistance; however, it forms an undulating terrain with a moderate to low drainage density and shows a rather rough texture. It exhibits a light grey to grey tone on the 7-band images.

(8) Tocantins Group (PMt)

The group is divided into two units by the differences in tone on the 7-band images. The first unit shows a grey tone, a low resistance and a fine dendritic drainage pattern. The second unit has a very dark tone because of sparse vegetation. It exhibits a higher resistance than the first unit.

(9) Gurupi Formation (PSg)

The formation exhibits a low resistance and a grey tone on the 7-band images. A bedded structure is clear on the images.

(10) Pimenteiras Formation (Dp), Cabecas Formation (Dc) and Longa Formation (DCl)

These three formations show the similar image characteristics such as low resistance and low drainage density. They form a flat terrain.

(11) Poti Formation (Cpo) and Piaui Formation (Cpi)

These formations have the same image characteristics. They show a low resistance and form even topography. The drainage is dense and has a dendritic pattern.

(12) Pedra de Fogo Formation (Ppf)

The formation shows two types of image characteristics. The first unit located around Rio Tocantins and Rio Araguaia, has a moderate to low drainage density, a low resistance and a low relief. The second unit located in the southern part, forms a flat plateau with low drainage density and shows a dark grey tone on both of the 5-band and 7-band images.

(13) Motuca Formation (PTRm)

It shows a light tone on the 5-band images and a light grey tone on the 7-band images. The drainage is dense and has a fine dendritic pattern. In the southern part this formation forms a low land surrounded by the plateau of the Pedra de Fogo Formation.

(14) Sambaiba Formation (TRs)

This formation exhibits a grey tone on the 7-band images and a very light tone on the 5-band images, for the vegetation is sparse. The formation also shows a low drainage density and a low resistance.

(15) Mosquito Formation (TRjm)

This formation exhibits a grey tone on the 7-band images and a dark grey tone on the 5-band images, for the vegetation is rather dense. The drainage is moderately dense and has a subdendritic pattern. The formation has a moderate resistance and forms small isolated hills on the low land formed by the Sambaiba Formation.

(16) Pastos Bons Formation (Jpb)

This formation shows a dark tone on the 5-band images and a grey tone on the 7-band images, for the vegetation is dense. The drainage has a medium density and a subdendritic pattern. The formation forms a low land.

(17) Corda Formation (Jc)

It shows a grey tone on both of the 5-band and 7-band images. It forms a flat plateau with low drainage density and is surrounded by the low land formed by the Pastos Bons Formation.

(18) Sardinha Formation (Ks)

This formation is restricted in distribution and shows the same image characteristics as the Grajau Formation and the Itapecuru Formation.

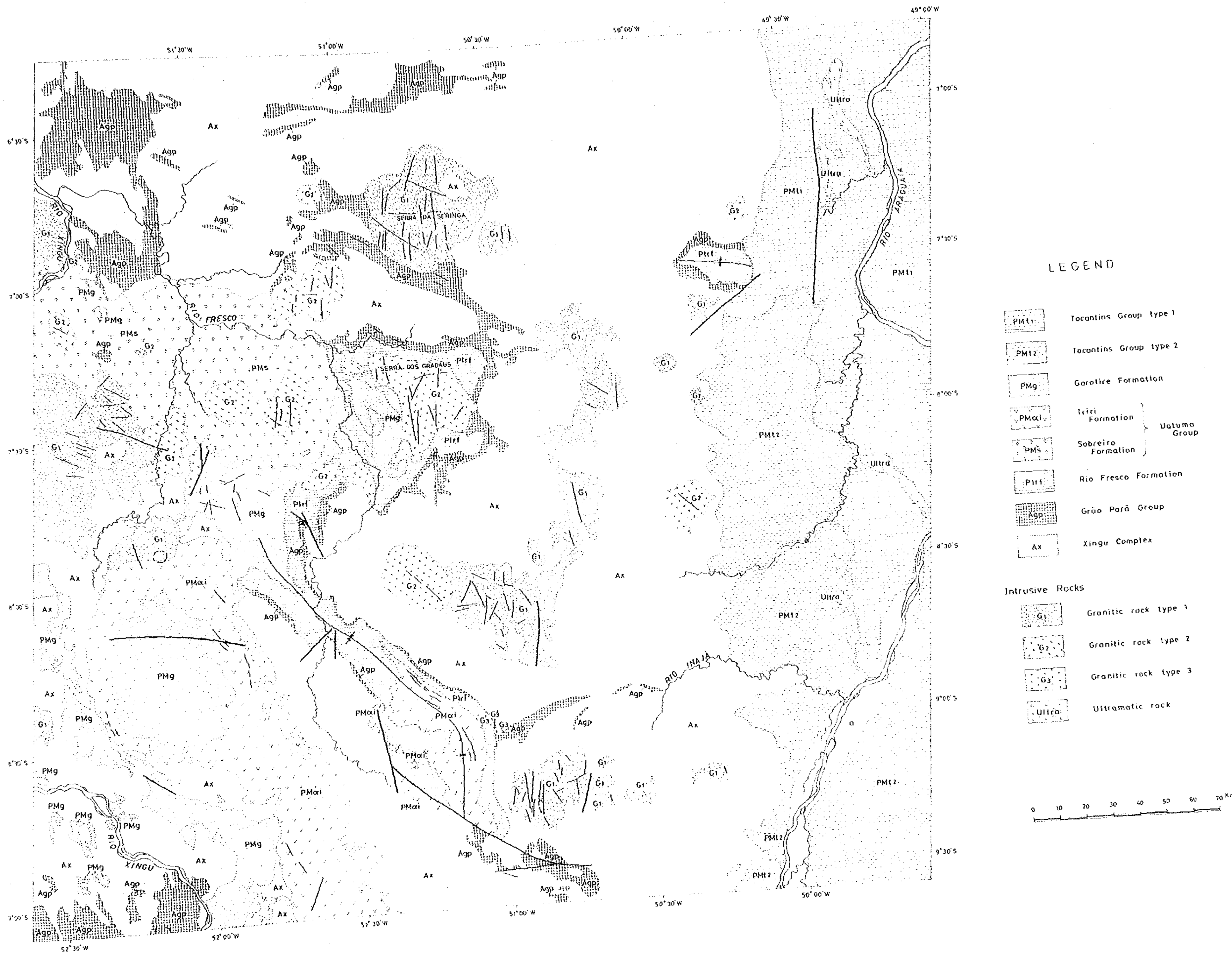
(19) Codo Formation (Kc) and Grajau Formation (Kg)

Codo Formation exhibits a dark tone on the 5-band images and a grey tone on the 7-band images. It exhibits a low resistance and forms a flat low land. Grajau Formation shows a moderate to low resistance and exhibits a higher resistance than the Codo Formation. This formation has a dense vegetation because it shows a dark tone on the 5-band images and a light tone on the 7-band images. This formation is similar to the Corda Formation; however, the former exhibits a lower resistance and a heavier vegetation than the latter.

(20) Itapecuru Formation (Ki)

This formation generally shows the same image characteristics as the Grajau Formation; however, it has a coarse dendritic drainage pattern with a U-shape valley in some areas.

Figure 4-5 Interpretation Map of Landsat Images covering the Inaja and Serra dos Gradaus Areas



(21) Alter do Chao Formation (KTac)

No exposed area of this formation is included in the Landsat data obtained this time.

(22) Barreiras Group (Tb)

This group shows a grey tone on the 7-band images and a low drainage density. It has a moderate resistance and mostly forms an even terrain. It overlies the Itapecuru Formation with a horizontal structure.

(23) Quaternary formations (TQc, Qal)

Quaternary formations form a flat low land and are restricted in distribution.

(24) Intrusive rocks

(a) Granitoid (APIγ)

It shows a light tone on the 7-band images and forms a rugged terrain. The image characteristics of this rock are similar to those of Serra dos Carajas Granite; however, the resistance of the former rock is higher than that of the latter.

(b) Serra dos Carajas Granite (PMγc)

This granite forms an uneven and rugged topography and has a higher resistance than the granitoid. It shows many lineaments due to jointing and faulting.

(c) Velho Guilherme Granite (PMγv) and Suite Intrusiva Redencao (PSγr)

These two rock types exhibit the same image characteristics; therefore, it is difficult to differentiate them. They can be discriminated from other intrusive rocks because they are shown in a dark tone on the 7-band images due to sparse vegetation. They form uneven topography; however, hilltops are rounded.

(d) Ultramafic Rocks(v) in the Tocantins Group

This rock type exhibits a rather high resistance and forms a rugged terrain. Contrary to the granitic rocks, this rock forms elongated exposures.

4-4 Principal Mineral Ore Deposits and their Geology

(1) Gold Deposits

Gold is the most widely distributed mineral around the Brazilian shield and the auriferous districts are as follows:

a) Quadrilatero Aurifero (Minas Gerais: MG)
b) Southern extension of Guiana (Amapa: AP)
c) Gurupi - Maracacume (Para: PA)
d) Rio Tapajos (Amazonas: AM)
e) Paraguai - Cuiaba (Mato Grosso: MT)
f) Central - Northwestern area of Goias (Goias: GO)
g) Jacobina (Bahia: BA)
h) Chapada - Diamantina (BA)
i) Rio Grande do Sul (Rio Grande do Sul: RS)
j) Rondonia stanniferous area (Rondonia: RO)
k) Carajas area (PA)

The major types of deposit are of alluvial and/or elluvial, although there are also some primary deposits such as those mentioned in the above items a), f), g), i) and k). Currently there is very little information available as to the former types of gold deposits because they have been mined only at a small scale by local miners known as "garimpeiro." Those small mines, or "garimpos," have been in operation since the colonial period in the 17th century. No substantial record had since been kept.

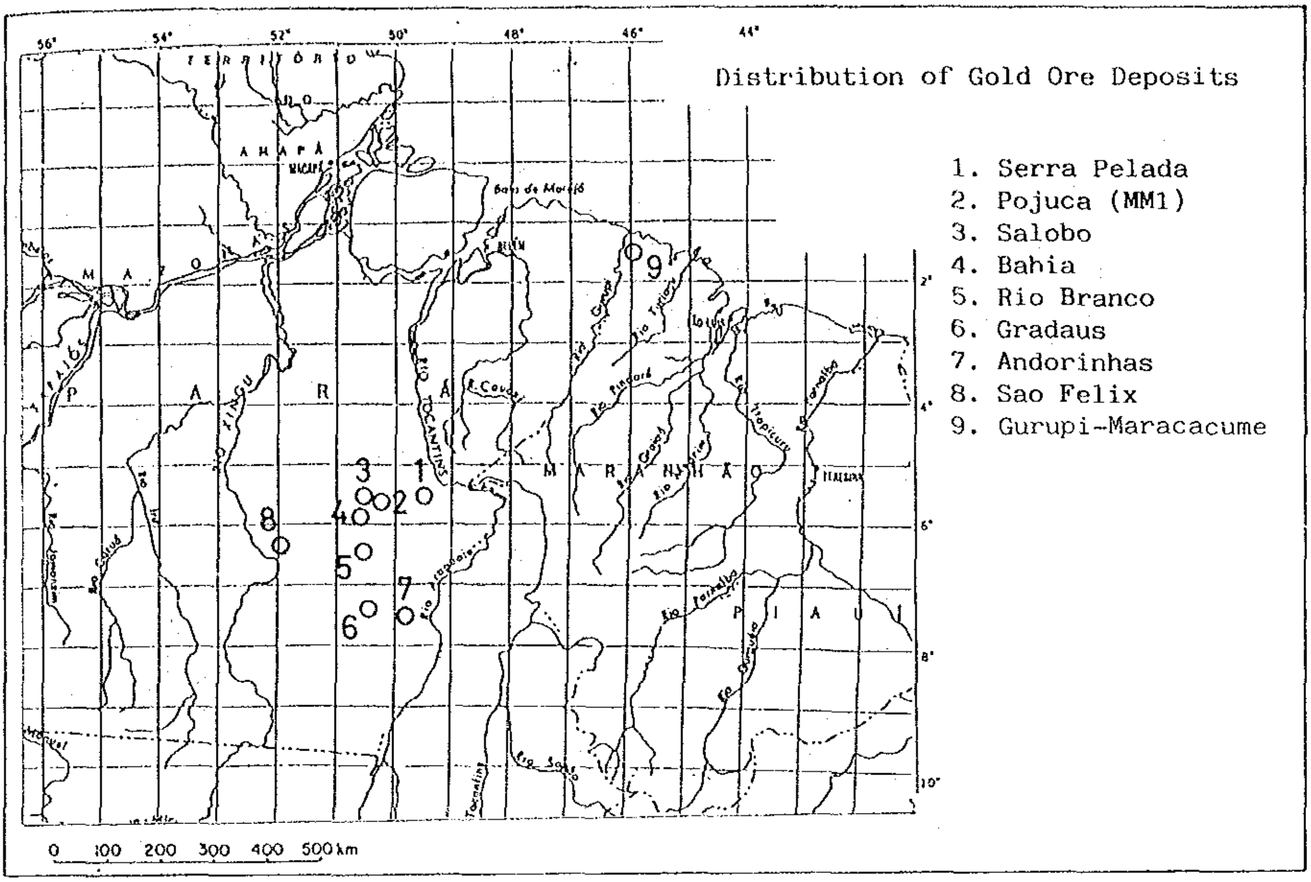
In 1982, a total of 24.8 tons of gold were mined in Brazil. Gold production in the state of Para in that year accounted for 63% of the total Brazilian gold production as shown in the following regional breakdown of production ratio:

Tapajos	30%
Serra Pelada	26%
Morro Velho	17%
Alta Floresta	7%
Cumari	6%
Rio Madeira	5%
Others	9%

The auriferous area in Serra das Andorinhas of the Carajas district was discovered in 1977. The deposit discovered in the area is of gold bearing quartz vein, deposited with a sulfate horizon in meta-chert or chlorite schist. The remarkable gold deposit in Serra Palada was discovered in 1980 in pelitic beds of the Rio Fresco Formation. Since its discovery, this mine has greatly contributed to the increase in the production of gold in Brazil.

The reserve of gold in Eastern Amazonia is estimated at 1,800-1,900 tons. Figure 4-6 shows the distribution of gold deposits in the Greater Carajas Program Area.

Figure 4-6 Distribution of Gold Deposits in the Greater Carajas Program Area



Following is a geological review of principal gold deposits in the Amazon Region.

(a) Serra Pelada Gold Deposit

The first geological work in the area was carried out during the period of 1966/1967 by CODIM which discovered Mn occurrences in the eastern part of Sereno Structure and extended the reconnaissance survey to the western part as far as the Parauapebas River. In 1979 DOCEGEO carried out a geochemical survey of stream sediment in part of the Sereno Structure, aiming at finding base metals, without finding any important anomalies.

In January 1980, "garimpeiros" or local prospectors, discovered alluvial gold in the drainage presently called "Grota Rica." Thus began intense "garimpo" activity which increased with the discovery in March 1980 of nuggets at "Morro da Babilonia." Since that moment more than 10 tons of gold have been produced by the "garimpo." In May 1980, DOCEGEO began a detailed exploration program to evaluate the gold occurrences and to obtain necessary data to introduce rational mining.

The Serra Pelada "garimpo," placed some 90 km SW from the City of Maraba in the state of Para, covering an area of 200 m x 100 m where gold mineralization occurs, is associated with slightly metamorphosed sedimentary rocks of the Rio Fresco Formation, in an antiform structure with an approximate EW strike (Sereno Structure). Figure 4-7 shows the location of the Serra Pelada Gold Deposit and Figure 4-8 is a geological map of the Deposit.

Figure 4-7 Location Map of Serra Pelada

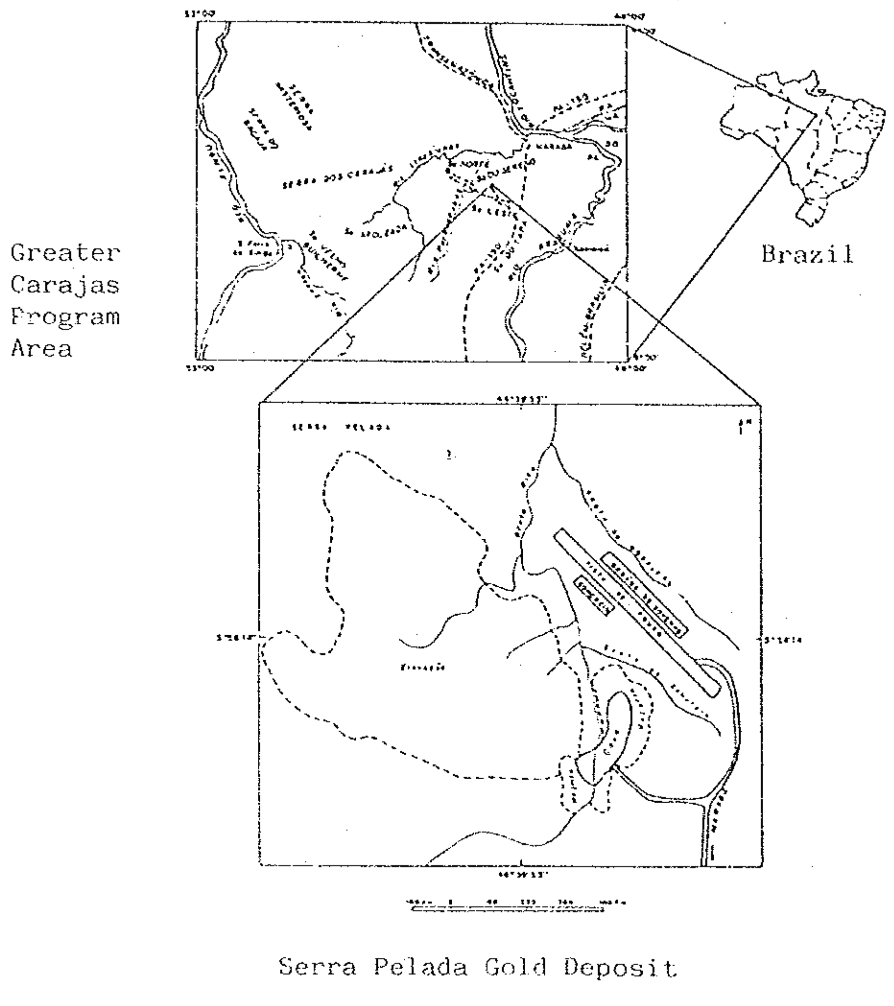
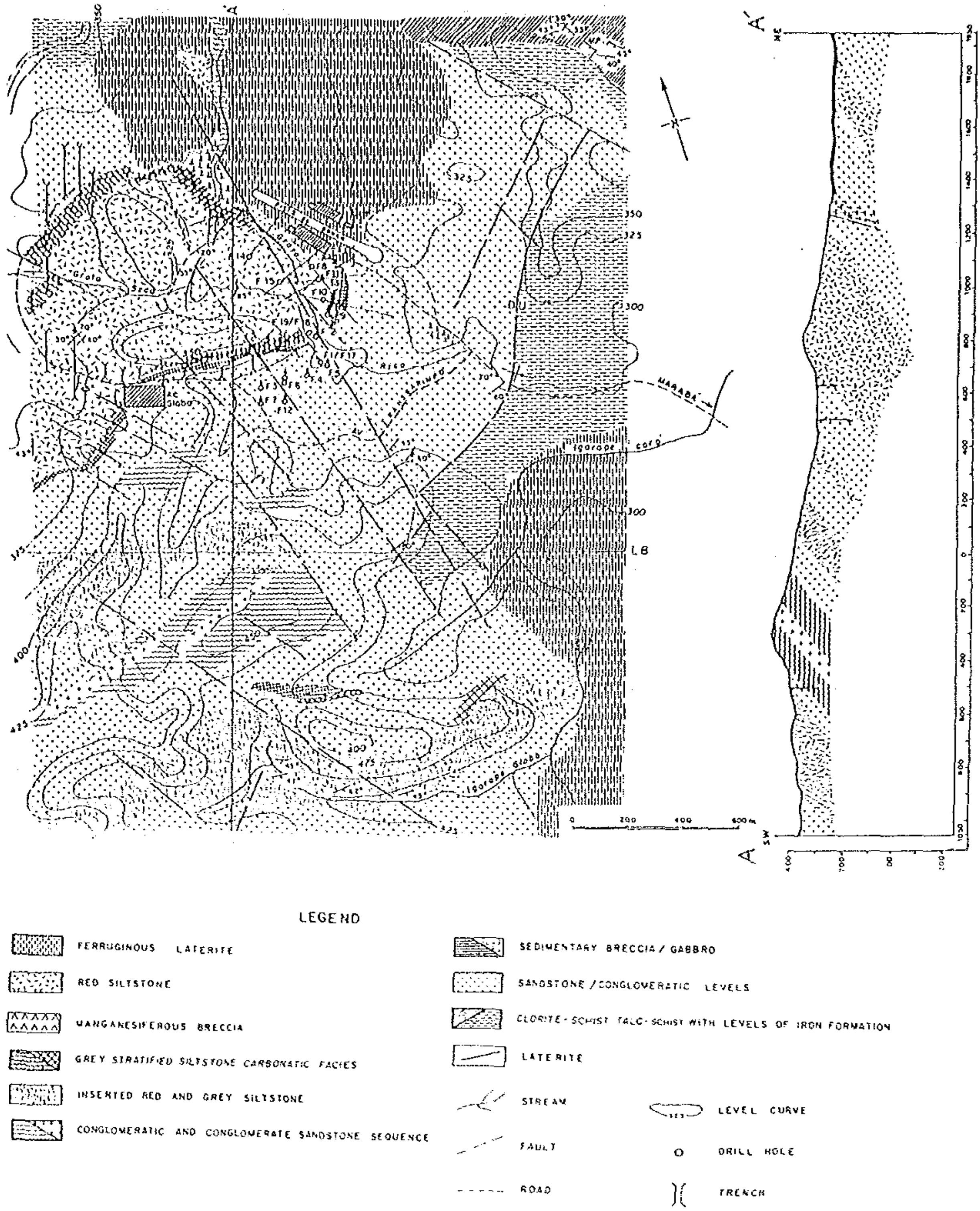


Figure 4-8 Geological Map of Serra Pelada Gold Deposit



Source: DOCEGEO

The basement to the direction of NNE consists of a sequence of mainly basic and ultra-basic rocks which are deformed, and with green schist facies metamorphism; and to the south, of itabirite with intercalations of basic rocks of Serra Leste. The regional geology is characterized by the presence of volcano-sedimentary and sedimentary belts. The volcano-sedimentary sequence includes meta-volcanic rocks, predominantly basic and ultra-basic, with small intercalations of felsic and chemical sediment (chert and iron formation). Gabbroic and dioritic bodies intrude in that sequence. The sedimentary sequence consists of coarse clastics in the base (conglomeratic sandstones, conglomerates and sandstones) and a pelitic unit in the top (grey and red siltstones and mudstones), correlative to the Rio Fresco Formation.

The structural characteristics of the region are complex and marked by superimposition of phases which suffered deformation mainly in the supra-crustals. The mine structure is a syncline of inverted flanks, dipping to the south and with a plunge to the west. Gold mineralization presents a lithological, tectonic and structural control - most parts of the gold concentration being related to the tectonic and structural control, in the region of the hinge folding.

Stratigraphically, major gold concentrations are found in the grey siltstone beds, manganese-ferrous breccia and at the grey-red siltstone interface. There is also mineralization in other beds but it is more erratic. Levels with sulphides (pyrite) in the grey siltstone having a reducing environment should be a mineralizing horizon of gold in view of the common association of those minerals with gold. However, gold is free, not associated with sulphides. Faults and folds played the most important role in the mineralization control. It is clearly seen in the "garimpo" area, where ENE faults are shifted by others of a north-west system, making the fault and fold zone an intensively tectonized area where there occurs rich mineralization, especially in the faulting crosses and folding crests.

Table 4-3 Ore Reserves of Gold Deposits in Brazil

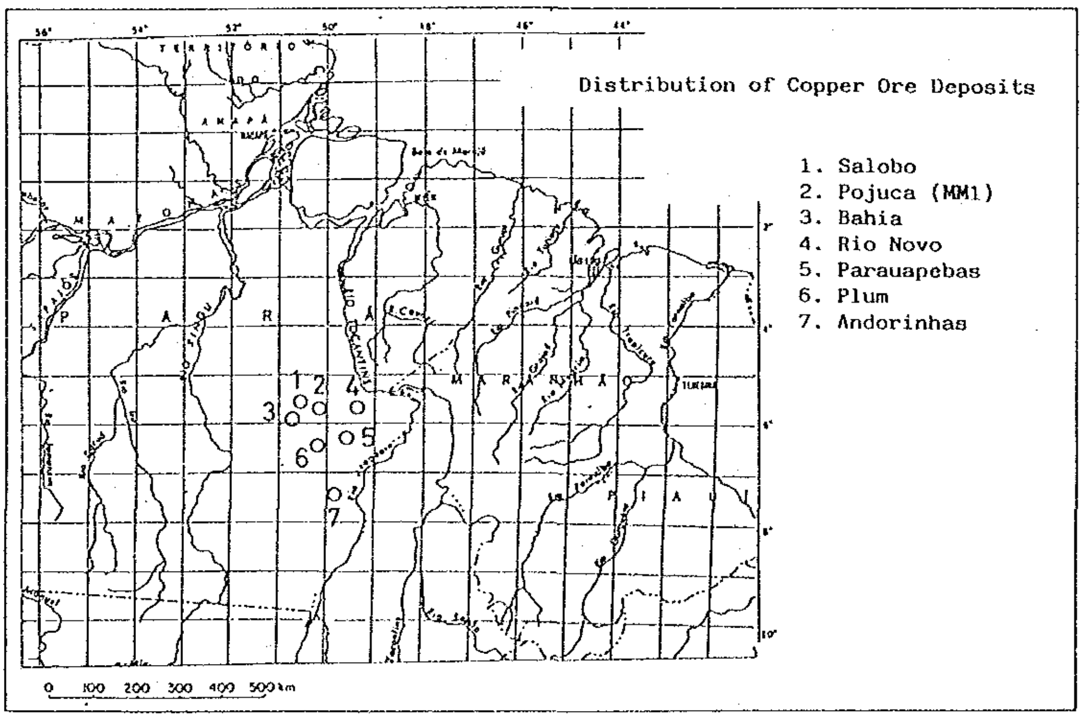
	Area	State	Mining Years	Produced Au (t)	Reserves million (t)	Reserves g/t	Reserves Au Content (t)	Type of Ore Deposits
Amazon Region	Gurupi-Maranhão	Maranhão	350	50			5	alluvial
	Amapá - Guiana	Amapá	130	250			133	"in situ"/alluvial
	Tapajos	Pará	25	150			900	"in situ"/alluvial CPRM 1982
	Sudeste do Pará	Pará	6	20			449	"in situ"/alluvial
	Paru - Jari	Pará, Amapá					14	
	Guajara Mirim	Rondonia			6.1	4.1	25	alluvial
	Altamira - Tocantins	Pará		5			12	
	Alta Floresta-Peixoto	Mato Grosso		10			1	
	Trombetas	Pará, Maranhão						
Other Areas	Araci	Bahia			4.1	7.7	32	
	Jacobina	Bahia			21.2	8.5	180	Witwatersrand
	Mara Rosa	Goias			202.5	0.44	89	greenschist with Cu deposit
	Diamantina	Minas Gerais			91.7	0.02	2	alluvial
	Mariana	Minas Gerais	300		48.3	5.5	266	
	Nova Lima	Minas Gerais			7.5	10.4	78	ferriferous bed
	Sabará	Minas Gerais			9.2	9.1	84	alluvial
	Gaspar	Santa Catarina			2.8	6.1	17	
	Morro Velho	Minas Gerais	150	300	4.0	15.0	60	schist
	Passagem	Minas Gerais			7.0	9.0	63	meta-schist

(2) Copper Deposits

Two copper mines: one at Caraiba in the state of Bahia and the other at Camaqua in the state of Rio Grande do Sul, became known only in the 1960s. Copper concentrates from these mines were refined at the Itapeva smelter in the state of Sao Paulo and the maximum production of copper metal in 1971 was 5,418 tons. The smelter, however, was closed in 1976. In the same year, a progressive and intense development of Caraiba and Camaqua mines began under a governmental order. By 1982, a new smelter at Camacari to which the copper concentrates from the above two mines were supplied, was in full operation and produced a total of 9,573 tons of copper metal in that year. In the meantime, exploration efforts were continued and other copper deposits have been discovered at Pedra Verde in the state of Ceara and at Mara Rosa in the state of Goias.

The outlook of copper production as well as the potential of this mineral resource in Brazil have been thoroughly revised with the discovery of a huge copper deposit at Salobo in 1977. The Salobo copper deposit is adjacent to the Carajas iron ore district and to the Mara Rosa deposit at Chapada in the state of Goias. The distribution of copper deposits in the Greater Carajas Program Area is shown in Figure 4-9.

Figure 4-9 Distribution of Copper Deposits in the Greater Carajas Program Area



(a) Salobo 3A Copper Deposit

The Salobo 3A copper deposit is situated in a metasedimentary-metavolcanic rock suite, forming a belt 70 km long striking N70°W, north of the northern flank of the Carajas synclinorium. The deposit was discovered in 1977, as a consequence of a geochemical survey of stream sediment carried out to check aligned aeromagnetic anomalies parallel to the Igarape Salobo valley. Chemical analysis subsequently showed high copper contents (up to 2,700 ppm).

Later soil geochemical surveys also showed high copper contents (up to 3,800 ppm) and a concurrent land geophysical survey (magnetometry and induced polarization) revealed anomalies of great lateral extension. Drillings, amounting to about 28,000 m in total up to November, 1981, permitted the measurement of 1.13 billion tons of copper ore reserve with 0.85% copper content. The lateral and vertical limits of the deposit, however, remain unknown. The mineralized and surrounding rocks were called "Salobo Sequence."

GEOLOGY (Figure 4-10)

The Salobo Sequence is constituted of a metasedimentary rock suite with subordinate basic metavolcanics, possibly of the Lower Proterozoic. Bedding, layering and schistosity are vertical or subvertical (dipping SW or NE) with a strike averaging N70°W. The Igarape Salobo Valley represents the approximate position of an isoclinal fold axis. As a consequence of a very accentuated disruptive tectonism, many fractures were developed, mainly striking N-NE and W-NW. The complex was metamorphosed to a high amphibolite facies and retro-metamorphosed to a greenschist facies.

The Salobo Sequence can be divided into five main stratigraphic units as follows (from the top to the bottom):

Quarzite
Upper Gneiss
Banded iron formation
Schists
Lower Gneiss

All of the sequence is cut by volcanic intrusive bodies of basic composition and acid intrusives (microgranites).

MINERALIZATION

The sulphide mineralization of the Salobo 3A deposit is represented by bornite and chalcocite (80-85%) and chalcopyrite. Usually, copper sulphides are associated with schists containing magnetite, with or without each of the following: amphibole, garnet, olivine and biotite.

The contact relations with the host rocks indicate syngenesis: the sulphides are disseminated, eventually constituting millimetric-centimetric levels parallel to the original structures. Massive levels of some centimeters thick rarely occur. In regard to copper sulphide distribution, an increase of a relative amount of chalcopyrite is noticed next to the schists unit base. Generally, mineralized olivinic schists also present larger proportions of chalcopyrite. Preferentially associated with the levels of copper sulphides, there are small amounts of gold, silver and molybdenite.

ALTERED ORE

Typically altered ores are the copper bearing intemperized schists and gneisses, the outstanding features of which are that no copper minerals typical of oxidation zones are present to justify the copper contents. Results from mineralogical investigation of this type of ore indicate that copper is associated with micas, clays and iron hydroxides. Small amounts of gold, silver and molybdenum occur in this kind of ore.

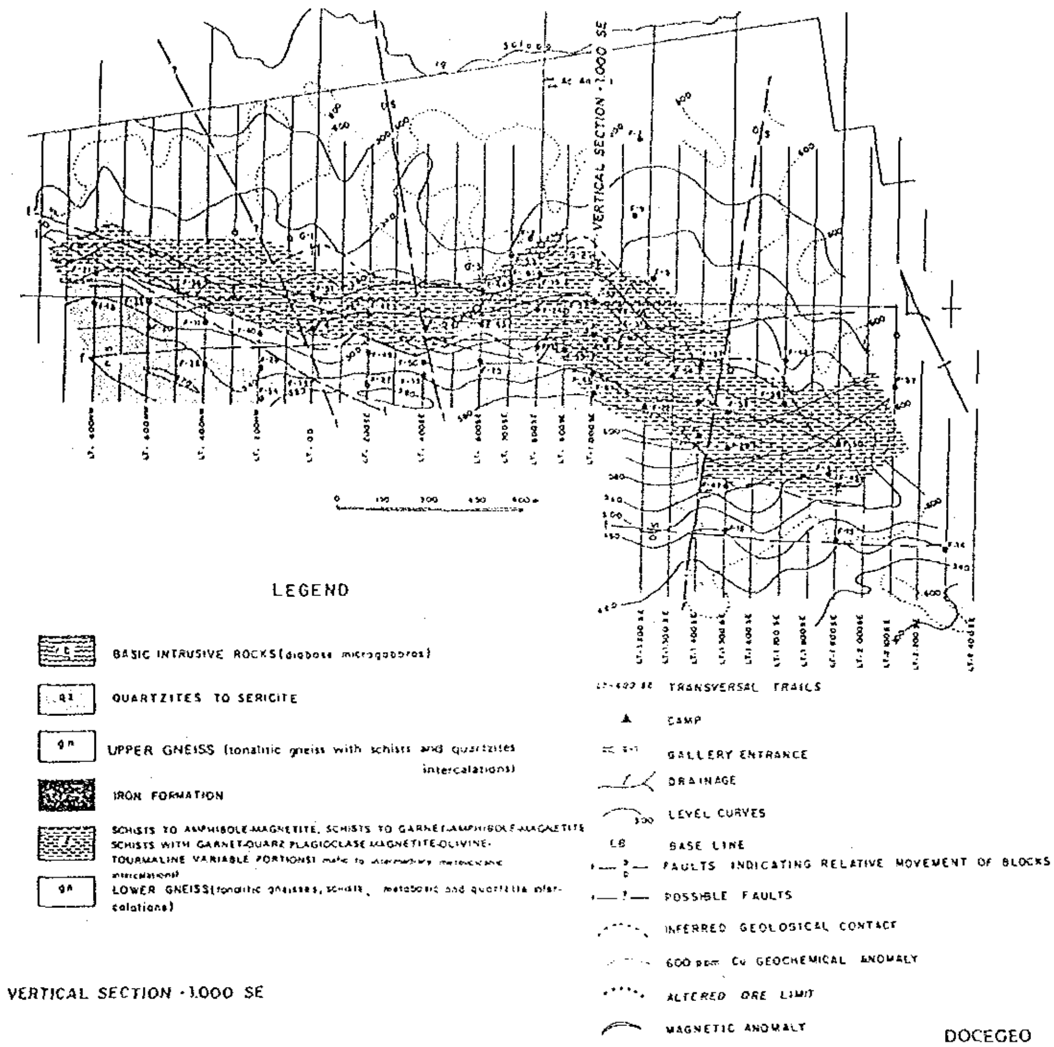
RESERVES

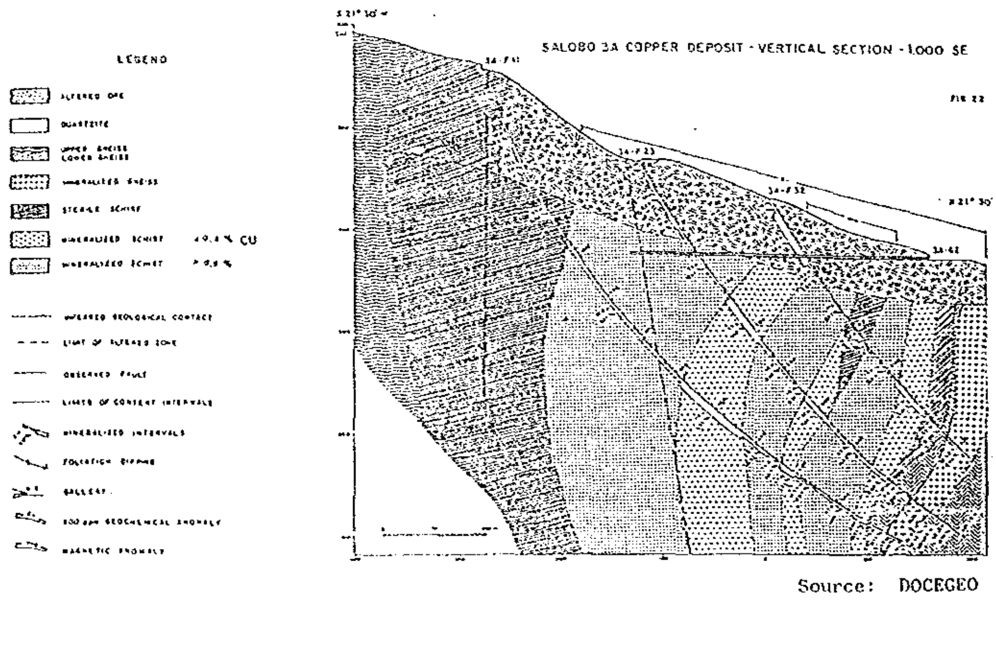
As noted above, an extensive drilling program performed in 1981 permitted the measurement of 1.13 billion tons of ore reserve with an average copper content of 0.85%. The table below shows a breakdown of the reserve into three different ore types:

Type	Tonnage (million tons)	(%) Cu
Sulphide ore >0.8% Cu	534.3	1.26
Sulphide ore <0.8 Cu	617.8	0.49
Altered ore	106.8	0.75
Average	1,258.9	0.83

Table 4-4 shows a respective ore reserve of copper deposits in Brazil in particular reference to the Salobo and Pojuca copper deposits in the PGC Area:

Figure 4-10 Geology of Salobo 3A Copper Deposit





Source: DOCEGEO

Table 4-4 Ore Reserves of Copper Deposits in Brazil

	Deposits	State	Reserves (million tons)		Grade Cu(%)	Grade Au g/ton	Remarks
Greater Carajas Program Area	Salobo 3A	Pará	Average	1,111.3	0.85	0.4-0.6	Jun.1981 DOCEGEO
			Sulphide ore>0.8%Cu	455.2	1.32		
			Sulphide ore<0.8%Cu	560.1	0.49		
			Altered ore	96.0	0.77		
	Salobo 4	Pará	Average	89.3	0.61		Jun.1981 DOCEGEO
			Sulphide ore > 0.8%	20.8	1.13		
			Sulphide ore < 0.8%	57.7	0.42		
			Altered ore	10.8	0.62		
	MM 1 (Pojuca)	Pará	Average	58.3	0.87	(Zn0.99)	1984 DOCEGEO
Other Areas	Caraiba (Jaguarari)	Bahia	Measured	112.0	1.22		1982 DNPM
			Probable+Possible	16.3			
	Curaça	Bahia	Measured	7.8	0.99		1982 DNPM
			Probable	1.6			
	Mara Rosa	Goias	Measured	155.5	0.40	0.44	1982 DNPM
			Probable+Possible	47.0			
	Americano do Brasil	Goias	Measured	4.3	0.67		1982 DNPM
			Probable+Possible	0.8			
	Bom Jardim de Goias	Goias	Measured	3.3	0.91		1982 DNPM
			Probable+Possible	1.2			
	Caçapava do Sul	R.Grande do Sul	Measured	7.9	0.70		1982 DNPM
			Probable+Possible	24.1			
	Lavras do Sul	R.Grande do Sul	Measured	3.4	1.0		1982 DNPM
			Probable+Possible	2.6			
	Viçosa	Ceará	Measured	7.7	1.12		1982 DNPM
			Probable+Possible	1.3			

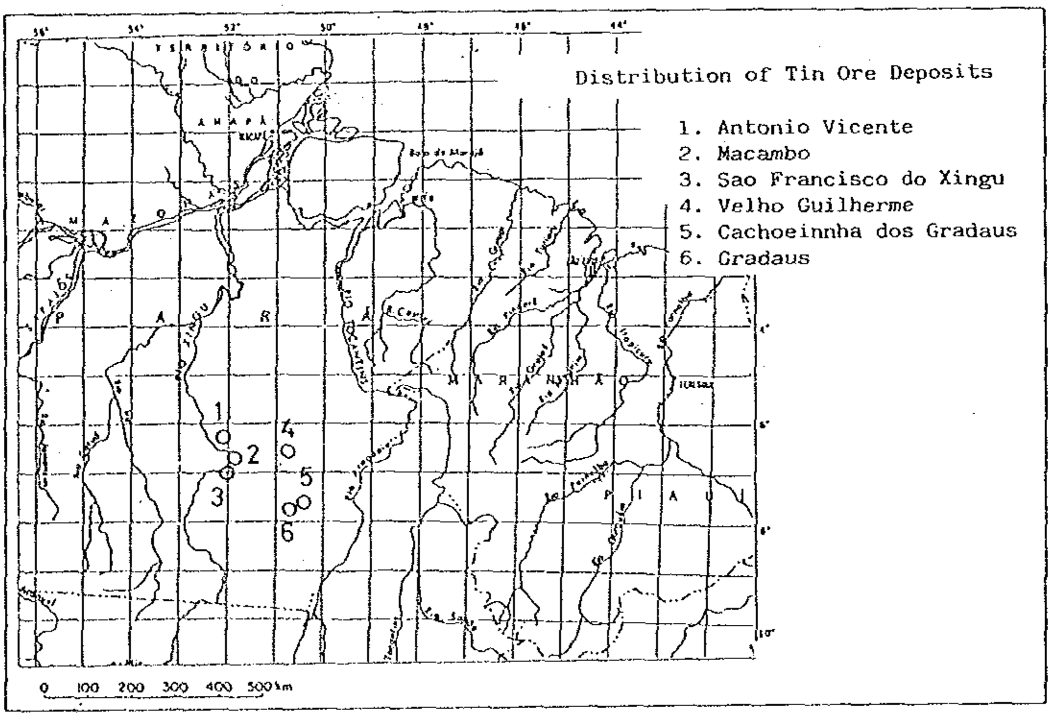
(3) Tin Deposits

The reserves of cassiterite were about 400,000 tons in 1982, showing a three-fold increase over some years ago owing mainly to an increase in production in the state of Rondonia. A total of 80% of the known reserves are concentrated in the states of Rondonia, Amazonas and Para.

A cassiterite deposit along the Tapajos river in the state of Para has been known since the 1960s. New deposits were also found in the 1970s at Mocambo and Sao Francisco to the south of Sao Felix do Xingu, and Antonio Vicente to the north. Recently a new deposit was found at Iriri in the Aruri Basin in the Xingu-Jamanxim district. A tin mineralized granite complex exists in the area from Araguaia to Tapajos known as "Provincia Estanifera do Sul do Para (Tin Province of Sul do Para)."

The distribution of tin deposits in the Greater Carajas Program Area is shown in Figure 4-11.

Figure 4-11 Distribution of Tin Deposits in the Greater Carajas Program Area



(a) Geology of Rondonia Stanniferous District

Geology of the Rondonia stanniferous district is principally composed of Precambrian base rocks and cretaceous, tertiary and quaternary intrusives of granite and diabase. The granitic complex which intrudes into the Palmeiral formation of upper Precambrian, are distributed over the center to the north of the Region with a total of about twenty intrusive bodies. The igneous complex exhibits a complicated character of volcanics to plutonics with an assemblage of pegmatitic granite, alaskite, porphyritic granite, granite-porphyry and rhyolite. The geologic time of intrusion of the complex is not determined, but is estimated at 940 m.y. The intrusives are circular or ellipsoidal with a diameter of 20 km around which a ring structure can be observed.

The tin deposits in the Region are alluvial and/or elluvial derived from the igneous complex and occupy an area as large as 600,000 km^2. Other minerals such as gold, diamond, manganese, titanium, wolframite, tantalum, etc. are also found in this area, although gold and tantalite are recovered only as by-products.

(b) Cassiterite Deposit in the Xingu Area

Many mineralized granitic bodies are known in the area. The alluvial deposit of Antonio Vicente was found in 1974.

Current reserves of tin deposits in Brazil are shown in Table 4-5.

Table 4-5 Ore Reserves of Tin Deposits in Brazil

	Area	State	Reserves		
			million m^3	Sn-content ton	g/ton
Amazon Region	Altamira	Pará	6.8	6,215	914
	São Felix do Xingu	Pará	26.5	14,893	562
	Mocambo	Pará		7,500*	
	Velho Guilherme			500*	
	Airao	Amazonas	66.0	87,344	1,323
	Manicore	Amazonas	1.9	653	340
	Ariquemes	Rondonia	7.8	4,878	627
	Porto Velho	Rondonia	106.4	66,997	629
	Apipuana	Moto Grosso	4.0	2,090	520
Other Areas	Cavalcante	Goias	134.6	44,024	327
	Monte Alegre	Goias	9.4	11,722	1,247
	Nova Roma	Goias	11.4	5,237	461
	Uruaçu	Goias	4.6	2,875	625

Source: ANUARIO MINERAL BRASILEIRO 1983, DNPM
Reserves are the sum of Medida, Indicada and Inferida
* AMAZONIA

(4) Nickel Deposits

The mineral assemblage of nickel ore in Brazil is classified as follows:

a) Ni - pyrrhotite - pentlandite - chalcopyrite
b) Ni - silicate

Principal deposits to be developed today are those of lateritic ore, although some massive and/or impregnated sulphide deposits such as the Americano do Brasil deposit, are known. Typical nickel deposits are derived from basic-ultrabasic intrusives of Sao Jose do Tocantins (Niquelandia), Barro Alto and Canabrava (Uruacu) in the state of Goias. The Niquelandia body occupies an area of 25 km (E-W) by 40 km (N-S), and is composed of norite, dunite, peridotite and pyroxenite in the lower section, and gabbro and anorthosite in the upper section. They are arranged as a belt elongated in a N-S direction. The Barro Alto body is situated about 30 km south of the Niquelandia body, and has an elongation of EW to NE, and diameters of 20 km x 150 km. The Canabrava body is located to the north of Niquelandia. The peridotite facies is altered to a serpentinized zone of 1-2.5 km in width and 20-30 km in length.

The laterite, originated from the peridotite, contains 1-2% nickel and occurs as pimelite in weathered decomposed products of serpentine. The laterite zone is composed of iron hydroxide rich in cobalt and manganese in the upper section, and of clay and iron minerals containing nickel and sometimes copper in the middle and transitional zones, and then of the original rock which has the highest concentration of nickel. The mineralized zone is about 5-20 m in thickness.

In addition, a large number of ultrabasic bodies distributed in the Araxa Group as well as alkaline ultrabasic rocks are mineralized in the same manner. The lateritic nickel deposits of Vermelho, Onca (Carapana) and Puma (Cateti) in the area between Araguaia and Xingu in the state of Para, are all derived from the ultrabasic complex. The distribution of nickel deposits in the Greater Carajas Program Area is shown in Figure 4-12 and the ore reserves of the nickel deposits in Brazil are shown in Table 4-6.

Figure 4-12 Distribution of Nickel Deposits in the Greater Carajas Program Area

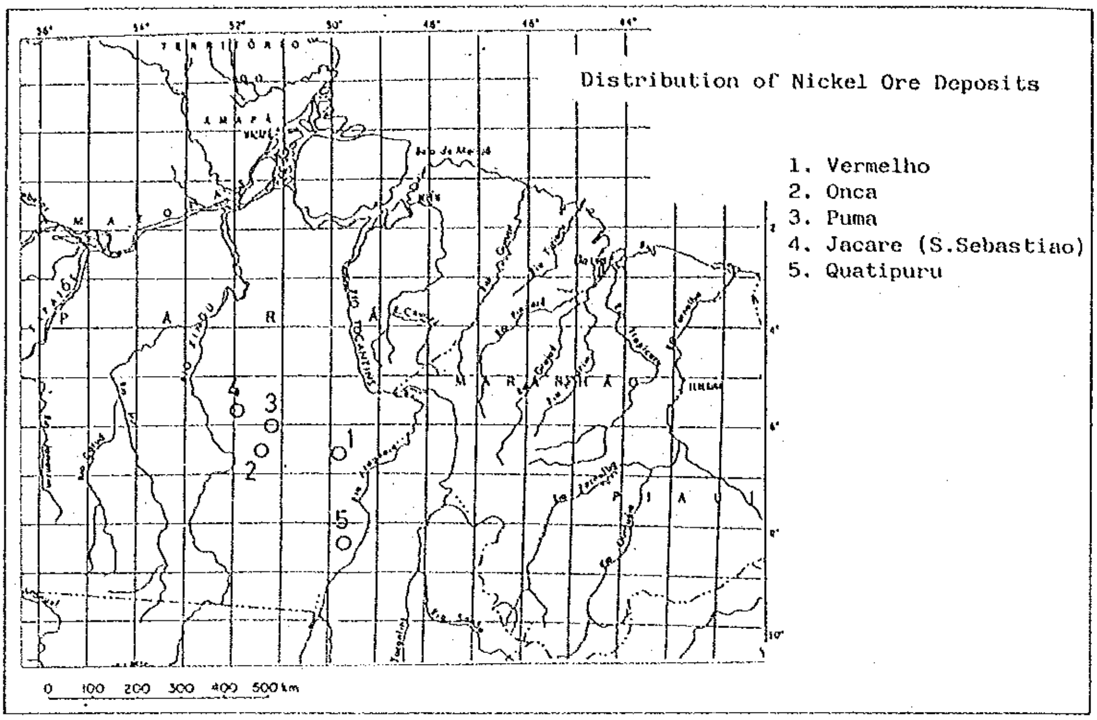


Table 4-6 Ore Reserves of Nickel Deposits in Brazil

	Area	State	Reserves million t	Reserves % Ni
Amazon Region	Vermelho	Pará	45.0	1.5
	Puma	Pará	24.8	2.2
	Onça	Pará	18.4	2.2
	Jacaré	Pará	23.4	1.2
	Quatipuru	Pará	13.0	1.3
Other Areas	Americano do Brasil	Goias	5.1	0.69
	Barro Alto	Goias	65.7	1.87
	Ipora	Goias	17.1	1.44
	Jaupaci	Goias	11.6	1.35
	Jussara	Goias	136.4	1.41
	Montes Claros	Goias	70.8	1.27
	Niquelandia	Goias	55.4	1.46
	Ipanema	Minas Gerais	7.3	1.45
	São João	Piaui	20.0	1.56
	Jacupiranga	São Paulo	3.3	1.39

(a) Laterite Nickel Deposit at Vermelho (Para)

There are two basic-ultrabasic bodies known, and they are composed of gabbro-metagabbro, noritic gabbro, pyroxenite or bronzitite, peridotite, sepentinite and selexite originated from dunite. They show almost the same rock facies and are surrounded by basement crystalline rocks (Xingu Complex) which are composed of granite gneiss, leuco granite, gneiss, quartz-diorite and amphibolite.

The basic-ultrabasic complex forms a plateau covered by laterite which is argillaceous and plastic and yellow or dark red in the inside although it is massive. Schistose and pisolitic canga are found at the surface. It is 5 m in thickness and is underlaid by a ferruginous saprolite zone (limonite type ore) and a garnieritic zone of 5-15 m in thickness successively. The grades of nickel are 0.3% Ni for fresh serpentine, 1.0-2.0% Ni for limonite type ore and 3-4% Ni for garnieritic type ore which is composed of argillaceous massive saprolite and saprolitzed serpentine. The following table shows reserves and grades of two types of nickel ore of Vermelho deposits:

Ore type	Thickness (m)	Area (10 m^2)	Reserves (10 tons)	Grade (%) Ni	MgO	Fe_2O_3
Garnieritic type	10.61	1,468	21,690	1.80	20.51	22.48
Limonite type	9.37	1,614	22,280	1.21	2.71	48.93
Total	9.99	3,082	44,000	1.50	11.49	35.88

(5) Manganese Deposits

The manganese ore reserves are estimated at about 20 million tons. The representative ore deposits are the Serra do Navio deposit in the state of Amapa, the Azul deposit in the state of Para and the Urucum deposit in the state of Mato Grosso. Ore types are as follows:

a) Sedimentary deposit in detrital sediment (Azul)
b) Meta-sedimentary deposit in siliceous carbonate sedimentary bed (Gondite and Serra do Navio)
c) Sedimentary deposit accompanied by a hematite bed (Urucum)

The distribution of manganese deposits in the Greater Carajas Program Area and ore reserves are shown in Figure 4-13 and in Table 4-7 respectively.

Figure 4-13 Distribution of Manganese Deposits in the Greater Carajas Program Area

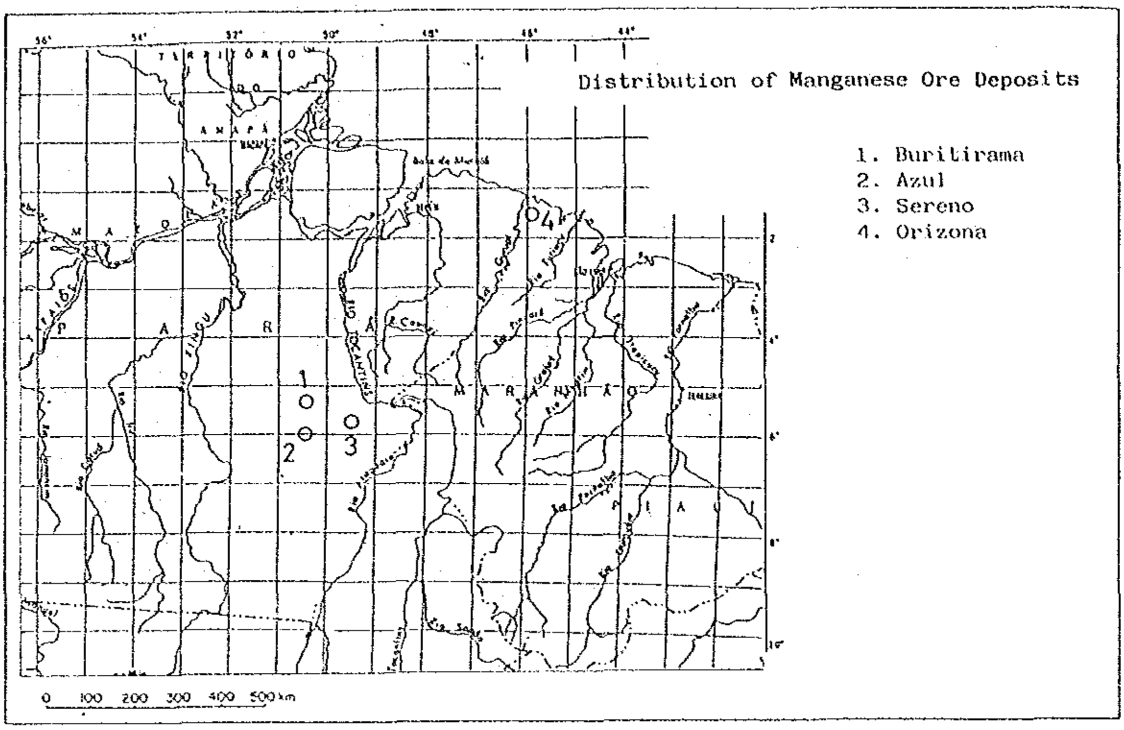


Table 4-7 Ore Reserves of Manganese Deposits in Brazil

	Area	State	Reserves	
			million t	% Mn
Amazon Region	Macapa(Serra do Navio)	Amapa	10.4	32.13
	Azul	Pará	45	42.20
	Buritirama	Pará	6.0	47.00
	Sereno	Pará	3.0	40.00
Other Areas	Marau	Bahia	2.5	34.68
	Corumba	Mato Grosso	71.3	42.88
	Ladario	Mato Grosso	31.9	43.00
	Conselheiro Lafaiete	Minas Gerais	3.9	31.47
	Ouro Preto	Minas Gerais	3.7	28.73
	Ritapolis	Minas Gerais	5.0	29.94

(a) Azul Manganese Deposit

The Azul manganese deposit is located 10 km south of the N1 iron ore deposit at Serra dos Carajas. It was discovered in 1971 during a regional geological reconnaissance. The deposit area constitutes a depressed basin with an average altitude of 550 m and differences in level of within 50 m.

EXPLORATION

The aim of the 1971 exploration in the mineralized area, was to evaluate detrital ore reserves and to obtain representative bulk samples for processing tests. Thus, 158 shafts were opened, totaling 2,530 m in length. The objective was to gather geological data and to characterize ore types underlying the detrital zone and its relation with associated rocks; therefore, 40 holes totaling 3,600 m in length were drilled.

The works involved in the geological mapping of the area are: topographical surveys; chemical analyses of shafts, holes and trench samples; granulometric tests of all channel samples collected in the shafts; several processing tests of ore in specialized laboratories. In addition, five trenches were opened.

GEOLOGY OF MINERALIZED AREA

The regional rocks are strongly altered, with rare outcrops. In the geological map there are marked only superficial formations from exogenous processes of weathering, desilication, laterization, lateritic carapace formation and supergene enrichment (Figure 4-14).

Flanking manganiferous block bands there are manganiferous pisolite bands of 300 m to 500 m in width in the northeast part, which sometimes are absent or only form narrow bands in the rest of the area. There are manganiferous lamellared materials, called plaquettes, frequently associated with pisolites. Locally, there occur blocks and plaquette fragments cemented by Fe and Mn oxide, constituting the so-called "lateritic manganiferous breccia."

In the more peripheral parts there are argillaceous or argillaceous sandy and reddish soils. In the northeastern and southeastern areas there are lateritic, concretionary and some ferruginous soils with local occurrences of true cangas. The rocks from the mineralized area, including manganiferous primary formations, are fine, argillaceous and, in part, silt/argillaceous. They constitute the pelitic sequence of the upper part of the Rio Fresco Formation, called "Membro Azul (Azul Member)."

The structure is interpreted as an asymmetrical anticline with an east-west axis, with a slight plunge to the east. The flank presents medium to strong dips on the south side and slight dips on the north side. This anticline contains smaller folding which can show local structural features. There were also found some NS and EW faults.

The stratigraphic column of "Membro Azul" can be summarized in the following sequence from bottom to top (see vertical section, Figure 4-14).

* At the bottom, there is a unit consisting of light grey to black siltstones and mudstones at a thickness of some 65 m with less than 14 % Mn.

* Above, there is a lower manganiferous unit of 18 m to 40 m in thickness with Mn content between 21% and 26%.

* Then, there is a 50 m-thick dark grey to black carbonaceous siltstone unit with less than 4% Mn.

* In the middle, there are light to dark and violet siltstones, constituting a unit of approximately 17 m to 44 m in thickness with less than 5% Mn.

* Above these siltstones occurs the upper manganiferous unit at a thickness between 33 m and 54 m with some 15% Mn content.

* At the top there are brown to red siltstones constituting a unit at a thickness up to 70 m with some 6% Mn.

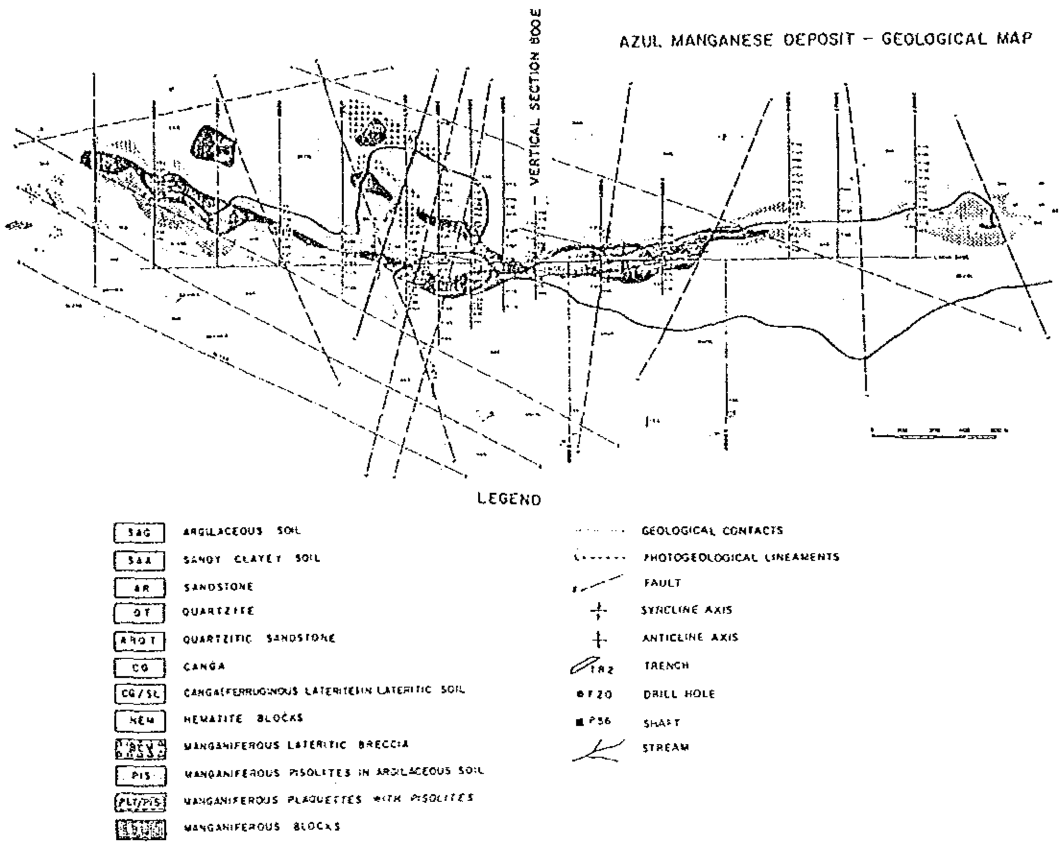
Among the manganiferous materials, three principal types are distinguished:

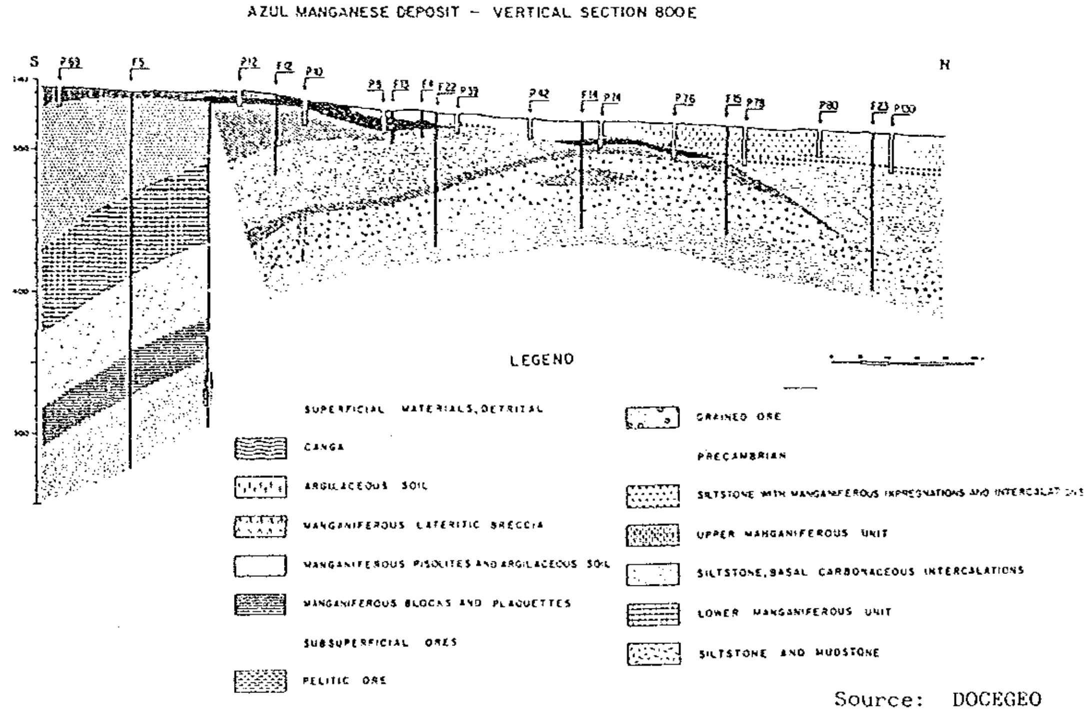
(i) Superficial deposits constituted of pisolites, manganiferous breccia, blocks and plaquettes (i.e., materials formed on the surface). They can reach more than 20 m in thickness, but the average thickness is 4 m. The manganese core is essentially constituted of cryptomelane, birnessite and lithiophorite, and the outer shell has gibbsite, kaolinite and goethite. After washing, they showed between 14% to 18% of Mn content but were not included as reserves.

(ii) Subsuperficial deposits which are essentially enriched, altered and manganiferous units in their original structure. They are friable with 20% to 30% Mn and reach 20 m to 60 m in thickness. The ore is richer in rhodochrosite than the upper unit.

(iii) Protores which are unaltered manganiferous units. They consist of chemical carbonatious layers of rhodochrosite and clastic layers of quartz and argillaceous-minerals, with a thickness of between 18-40 m and Mn content of 21-26%.

Figure 4-14 Geological Map of Azul Manganese Deposit





Source: DOCEGEO

ORE RESERVES

Detrital Ore: The total reserve of the "in-situ" detrital ore is 26.1 million tons with some 40% Mn and 14.5% Al_2O_3.

Pelitic Ore: The estimated total reserve of gross ore is 27.7 million tons with an average of 28.5% Mn content.

Grained Ore: "In natura," besides a high Mn content, the grained ore shows a Mn/Fe relation around 12. Its total estimated reserve is 11.5 million tons with 46.4% Mn.

(6) Bauxite Deposits

Brazil is the third in the world in its bauxite reserves next only to Guinea-Bissau and Australia. The reserves of bauxite were estimated to amount to a total of about 4.2 billion tons in 1982. The state of Para holds more than 90% of the reserves. The production of bauxite in 1982 was 4.2 million tons and more than 90% of this amount was supplied to produce 585,000 tons of alumina and 299,000 tons of aluminium.

The principal types of bauxite are represented by those at Pocos de Caldas, State of Minas Gerais, which are originated from Cretaceous/Tertiary alkaline rocks and by those at Trombetas and Paragominas in the Amazon region, which are derived from lateritic intemperism of continental sediments during Early Tertiary, probably in Eocene-Oligocene times. The distribution of bauxite deposits in the Greater Carajas Program Area is shown in Figure 4-15. The reserves of bauxite, and aluminium refineries in Brazil are shown in Table 4-8.

Figure 4-15 Distribution of Bauxite Deposits in the Greater Carajas Program Area

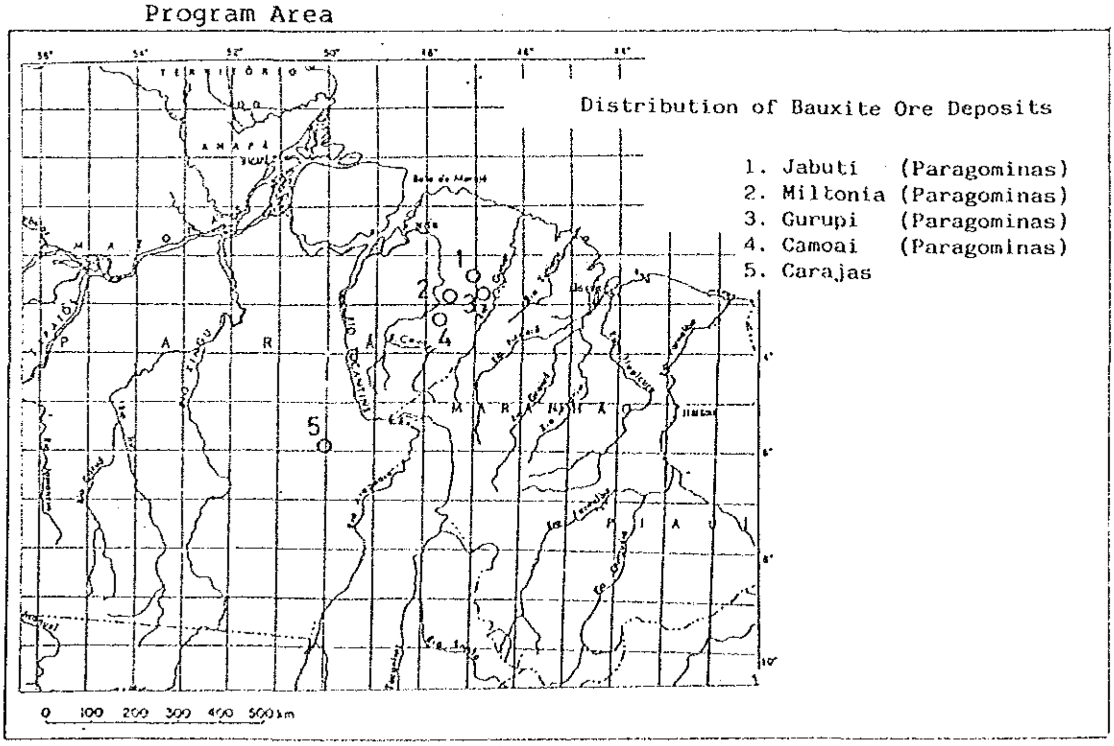


Table 4-8 Bauxite Ore Deposits and Aluminium Refineries in Brazil

	Bauxite						Alumina and Aluminium			
	Ore Deposits	Location (state)	Company	Reserves (million tons)	Production (1,000 tons)	Plan (1,000 tons)	Refinery Company	Location	Production (1,000 tons)	Plan of Investment 1,000 tons and US$ million
Southern Area	Poços de Caldas	MG		Total 80						
			ALCOMINAS		232		ALCOMINAS	Poços de Caldas-MG	Al 90 -(1983)	
			ALUCALDAS		5					
	Barreiras	MG	CBA		300		CBA	Sorocaba-SP	Al 120-(1983)	Al 160-(1980-1990) US$7.4
	Quadrilatero Ferr.	MG	ALUCALDAS	25	400		GRUPO ALCAN			
	Passa Quatro	MG	CBA	20			ALUMINAS	Saramenha-MG	Al 60 -(1983)	
	Espinhaço	MG		20			ALUNORDESTE	Aratú-BA	Al 58 -(1983)	(imported Alumina)
Amazon Region	Trombetas	PA	Min. Rio de Norte	800	3,400-(1983)	4,700-(1984)	ALUNORTE	Barcarena-PA		Alumina 600-(1985) 800-(1989) US$700
						2,700-(1988)	ALBRAS	Barcarena-PA		Al 75-(1985) 320-(1989) US$1,800
			(Trombetas) 860				ALUMAR	São Luis-MA		Alumina 500-(1984) 1,000-(1987) 1,500-(1989) Al 100-(1984) 150-(1987) 300-(1989) US$1,000
	Nhamunda	PA	SAMISA (ALCOA)	260		5,000-(1980-1990)	ALCOMINAS	(Norte or Nordeste)		Alumina 500, Al 100-(1984)
	Futuro, Jabuti Gurupi	PA	CVRD	1,100			ALUNE	Recife-PE		Al 50-(1985) 86-(1989) US$659
	Vera Cruz	PA	RTZ (Paragomina) 2,350	1,000						Alumina 200-(1988) US$200
	Paragominas	PA	CBA	250			VOTORANTIM	(Paragominas)-PA		Al 160-? US$536
	Jari	PA	Ludwig	240					Al 24 -(1982)	
	Jariti	PA	Reynolds	170			VALESUL	Santa Cruz-RJ	Al 85 -(1985)	
	Almeirim	PA	CVRD	(Jari) 760 200						
	Almeirim	PA	Ludwig	150						
	Carajas	PA	CVRD	120						
BRAZIL TOTAL				4,235	4,200-(1982)	(1980-1990) 15000-	BRAZIL TOTAL		Alumina 585-(1982) Al 414-(1983)	Al 1,300 - (1980-1990)

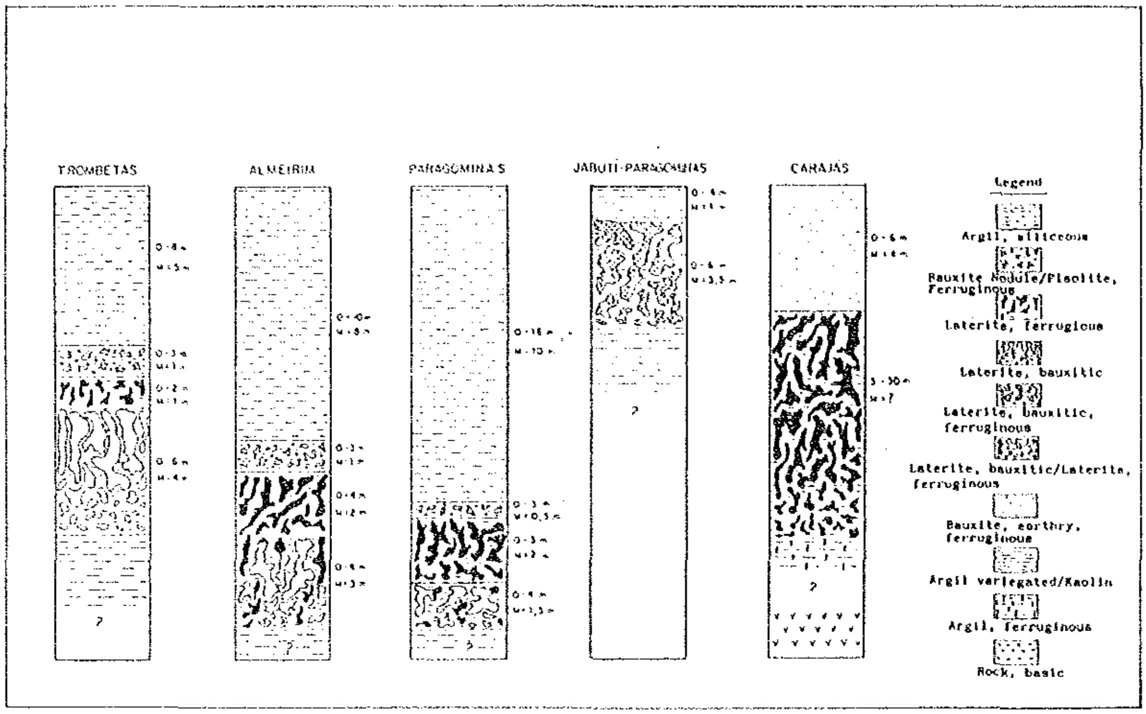
ALBRAS - Aluminio Brasileiro Ltda. : CVRD 51%, Nippon Amazon Aluminium Co. - NALCO (NAAC) 49%
ALCOMINAS - Cia.Mineira de Aluminio : ALCOA, Hanna Mining, etc.
ALCAN - Alcan Aluminio da America Latina S.A. : ALCAN
ALUMAR - Aluminio do Maranhão S.A. : ALCOA, Shell
ALUNORTE, Vereinigte Aluminium - Werk A.G.
ALUNORTE - Aluminio do Brasil Nordeste S.A. : CVRD, NALCO
CBA - Cia. Brasileira de Aluminio : Group Vatorantim
VALESUL - Valesul Aluminio S.A. : CVRD 61%, Shell 35%, Reynolds 4%

(a) Bauxite at Trombetas (Para)

Bauxite has been found in the right fork of the Trombetas river and in the north side of the Amazon river.

The deposit is formed by an enrichment of alumina of argillaceous bed of the Barreiras Formation of the Tertiary age. The following columnar sections (Figure 4-16) show schematic profiles of bauxite deposits in Brazil including the one at Trombetas:

Figure 4-16 Schematic Profile of Bauxite Deposits



Source: DOCEGEO

As shown above, bauxite deposits generally consist of the following units:

a)	argillaceous surface	about 6 m in thickness
b)	nodule bauxite	about 1 m "
c)	ferruginous laterite	about 1 m "
d)	massive bauxite composed of crystalline gibbsite	about 5 m "
e)	argillaceous kaolin bed	
f)	non-consolidated sandstone	

The nodule bauxite is composed of massive bauxite in argillaceous matrix. The massive bauxite is hard and brittle, or blocky depending on the depth. Gibbsite is a common mineral of aluminium with a little boehmite.

(b) Bauxite at Paragominas (Para)

The prospective area of Paragominas covers a vast area of more than 20,000 km^2, located 200-300 km south of the city of Belem. The bauxite deposit of Paragominas is similar to that of Trombetas. It lies almost horizontally and is derived from fine sandstone and siltstone of the Barreiras Formation by the enrichment of alumina. There are two types of ore as follows:

(i) RTZ type (Trombetas bauxite)

The ore is composed of nodular bauxite, ferruginous laterite, and bauxite laterite and is very easy to treat for dressing. This type of ore is also found at the Trombetas deposit.

(ii) Jabuti type

The ore body exhibits vertical-tube or stream-like shapes and is mixed with clay. This is a very fragile ore and is very difficult to dress.

(7) Iron Deposits

Among the mineral resources exported from Brazil, iron ore is the most important resource, although the domestic supply of steel is not enough to make Brazil self-sufficient. The current iron ore reserves of Brazil are 32 billion tons, which is the third largest amount in the world. The Carajas deposit is the largest metal ore deposit discovered in the 20th century.

The distribution of iron deposits in the Greater Carajas Program Area is shown in Figure 4-17 and the reserves of iron ore in Brazil are shown in Table 4-9.

Figure 4-17 Distribution of Iron Deposits in the Greater Carajas Program Area

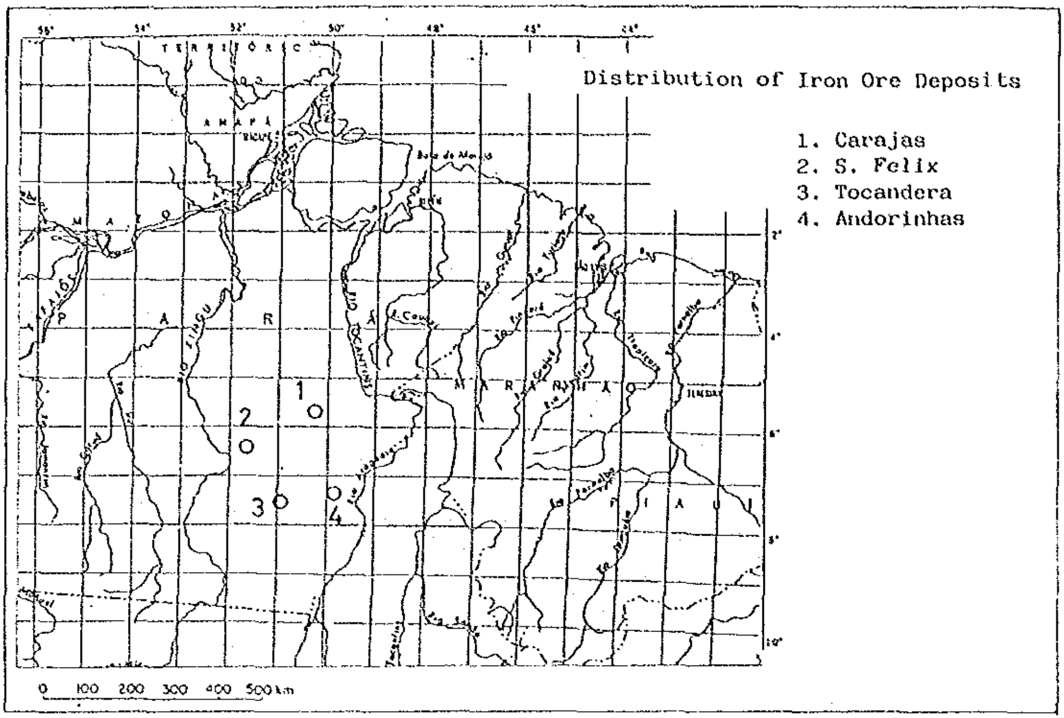


Table 4-9 Ore Reserves of Iron Deposits

Company	Mine	Location	Reserves million tons	Production million tons	Remarks start of operation
CVRD	Caue	Itabira	$1,100^{60\%Fe}$	$35.0^{65\%Fe}$	1934, Mill:1973
CVRD	Conceiçao	Itabira	329	15.0	Mill:1979
CVRD	Piçarrão	Nova Era	34	1.5	1969, Mill:1972
CVRD	Timbopeba	Mariana	170 460 (itabirite)	7.5	Mill:1981
CVRD	Itavale	Itabira		3.5	
CVRD	Caraça	Sta. Barbara		2.0	
CVRD	Dois Corregos	Itabira	$64^{67\%Fe}$		
CVRD	Jirau			0.5	1970
MSG	Capanema	Sta. Barbara	$1,000^{40\%Fe}$	(8.0)	1982
MSG	Serra da Piedade	Sabará	394		
MBR	Aguas Claras	Nova Lima	$235^{68\%Fe}$	$12.0^{68\%Fe}$	1973
MBR	Pico de Itabirito	Itabirito	400 $232^{66\%Fe}$	$1.5^{67\%Fe}$	1942
MBR	Mutuca	Nova Lima	320	$2.5^{67\%Fe}$	1961
MBR	Jangada	Brumandinho	$60^{60\%Fe}$	$1.3^{67\%Fe}$	1962
MBR	Samambaia	Brumandinho	$8^{60\%Fe}$		
MBR	Vigario de Vera	Sta. Barbara	$240^{61\%Fe}$		
SAMITRI	Corrego do Meio	Sabará	394	$0.2^{64\%Fe}$	1953
SAMITRI	Alegria	Mariana	$350^{60\%Fe}$ $17,000^{40\%Fe}$	3.2	1969
SAMITRI	Morro Agudo	Rio Piracicaba	10	$0.8^{64\%Fe}$	1963 } Piracicaba Complex
SAMITRI	Andrade	Monlevade	120	$0.8^{66\%Fe}$	1971 } Piracicaba Complex
SAMITRI	Jacutinga				
SAMARCO	Germano	Mariana	389	$2.2^{50\%Fe}$	Fl.conc.1.5million t 67%Fe
FERTECO	Corrego do Feijão	Brumandinho }	326	4.5	
FERITECO	Fabrica	Ouro Preto }			
FERTECO	João Pereira	Congonhas	$222^{760\%Fe}$		
CSN	Casa de Pedra	Congonhas	$32,000^{40\%Fe}$	3.0	
HIME	Dois Irmãos	Barao de Cocais		(4.0)	Fe-Mn, 1982
MANNESMANN	Mutuca I, II	Nova Lima			
	Baú	Barão de Cocais	$350^{60\%Fe}$		
	Lagoa Seca	Belo Horizonte	$1,800^{61\%Fe}$		
	Ipanema	Ipatinga	13		
	Conta Historia	Ouro Preto	$1,500^{>50\%Fe}$		
	Brucutu	S. Gonç	$170^{59\%Fe}$		
	Morro Grande	Sta. Barbera	177		
Quadrilatero Ferrifero High Grade Ore Total			$10,400^{65\%Fe}$	101.0	
CVRD	Porteirinha	Rio Pardo	$3,500^{35\%Fe}$		
Minas Gerais High Grade Ore Total			13,528	101.0	
CVRD	Carajas Jatapu Morro do Urucum	Marabá Jatapu Corumba	$18,000^{65\%Fe}$ $150^{55\%Fe}$ $1,300^{>50\%Fe}$	(50.0)	(1985)
BRAZIL TOTAL			32,401	101.0	

(a) Carajas Iron Ore Deposits (Para)

The so-called "Serra dos Carajas Iron District" comprises a great number of deposits gathered in 4 groups: Serra Norte, Serra Sul, Serra Leste and Sao Felix. The first two are predominantly the most important, constituting the Carajas synclinorium flanks (Figures 4-18 and 4-19).

Figure 4-18 Location of Carajas Iron Ore Deposits

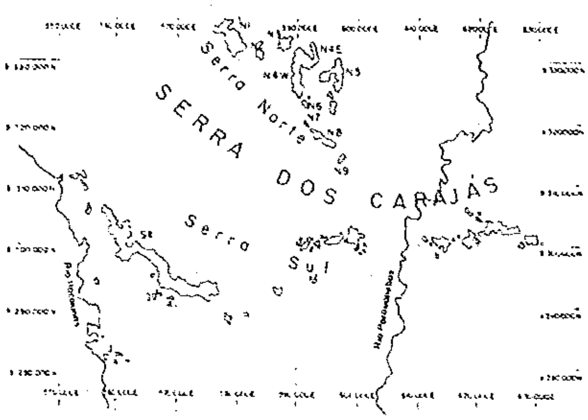
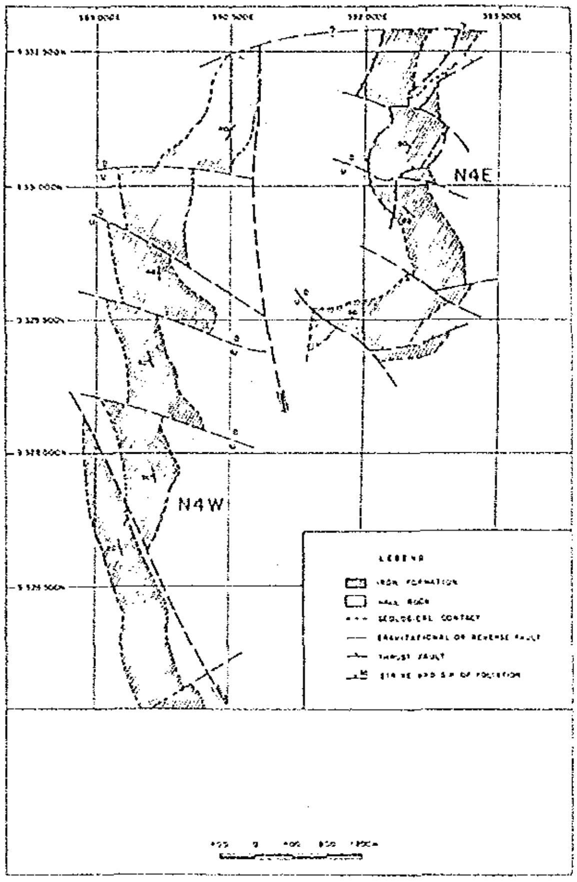


Figure 4-19 Geologic Sketch Map of the N4 Ore Deposit



Source: DOCEGEO

The current reserve estimation for the Carajas District is 17,884 million tons of minable iron ore, 88% of which is classified as a high grade type (Table 4-10).

Table 4-10 Iron Reserves in the Carajas District

ORE TYPE RESERVES

(million tons)

CLASS OF RESERVES	HIGH GRADE ORE > 64.0 % Fe		MEDIUM GRADE ORE 55.0 - 63.9% Fe		TOTAL RESERVES > 55.0% Fe	
	TONS	%	TONS	%	TONS	%
MEASURED	1,694	67.1	187	606	1,881	66.5
INDICATED	2,556	66 7	530	60.9	3,086	65.7
INFERRED	11,500	66 7	1,417	60 9	12,917	66.1
GRAND TOTAL	15,750	66.7	2,134	60 9	17,884	66.1

ORE RESERVES PER DEPOSIT

(million tons)

DEPOSIT	HIGH GRADE		MEDIUM GRADE		TOTAL
	TONS	% Fe	TONS	% Fe	TONS
N 1	794	66.8	59	61 1	854
N 2	101	66.4	9	610	111
N 3	243	66 1	55	60.1	297
N 4	2,622	66 6	557	61.1	3,178
N 5	1,371	67 1	208	60 1	1,579
N 8	124	66 4	28	62.1	152
S 11	9,475	66.8	860	61.1	10,335
SL 1	201	67 6	76	606	277
SL2	120	66 9	17	62 6	137
SF1	175	66 5	194	59 5	369
SMALL DEPOSITS	524	66 8	71	608	595
GRAND TOTAL	15,750	66 7	2,134	609	17,884

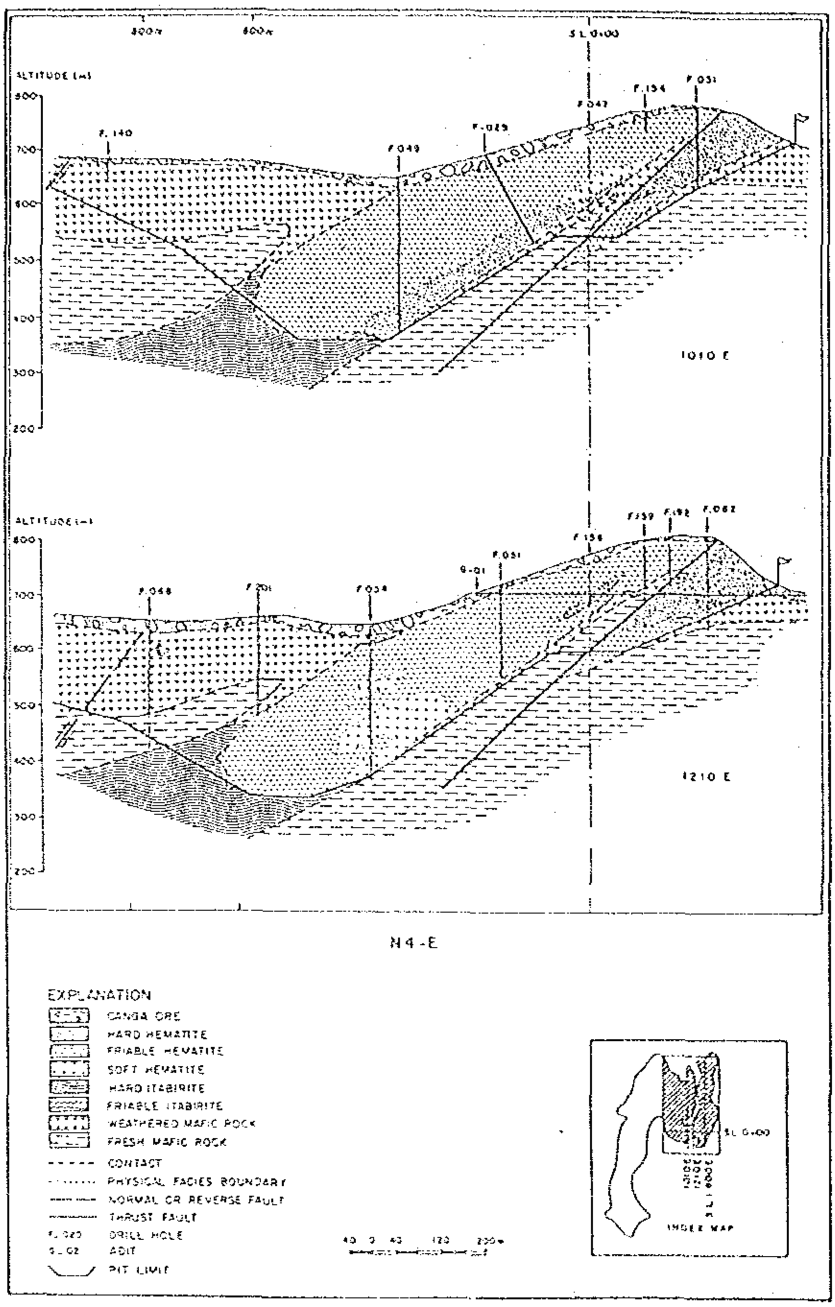
N4-E Iron Ore Deposit (Figure 4-20):

The N4-E orebody developed on a thick, extensive chemical-sedimentary iron formation called the Carajas formation, which is interlayered within mafic volcanic rocks. The sedimentary pile comprising the iron formation was significantly deformed under regional tectonic stresses. A relatively recent weathering process accounts for iron enrichment and ore genesis.

Originally classified as an itabirite, the N4-E protore was later defined as a jaspilite enriched into high grade hematite in a supergenic weathering environment. The protore was described as a low-metamorphic, oxide facies iron formation consisting of alternating quartz-chert and iron-silicate bands.

An original thickness of a protore layer was not observed at the N4-E deposit. Hematite ore, however, averages several meters in thickness.

Figure 4-20 Geologic Cross Sections of the N4-E Iron Ore Deposit



Source: DOCEGEO

4-5 Distribution of Principal Mineral Resources in the Greater Carajas Program Area

The principal mineral resources distributed in the Greater Carajas Program Area (the PGC Area) include Au, Cu, Sn, Ni, Mn, Fe and Al. Almost all the deposits in the PGC Area are concentrated in the Precambrian geology composing the Tapajos Craton. In particular, Au, Cu, Mn and Fe are related closely to the Grao Para Group and the Rio Fresco Formation. Sn is embedded within the granite of Velho Guilherme type and Ni, within ultrabasic intrusive rocks. Although Al is partly distributed in the Grao Para Group, it is mainly found in the Tertiary geology. The distribution of mineral ore deposits in the PGC Area are shown in Plate IV-1.

(1) Gold

Gold deposits in the PGC Area are represented by those of alluvial, vein and stratiform types, accompanied by sulphide minerals. Alluvial gold deposits distributed in the vicinity of Serra dos Carajas, the Cumaru area to the south of Serra dos Gradaus, and other areas such as Inaja, Bacaja and Rio Branco, are all been mined by "garimpeiros." The vein type gold deposits are associated with quartz veins, having a close relationship with the granite intrusion in metavolcanic rocks of the Grao Para Group, and are distributed mainly in the Inaja and Bacaja areas. The stratiform type is represented by the Serra Pelada mine located in Serra Leste.

Gold is concentrated where folding, faulting and breccia develop within black siltstone of the Rio Fresco Formation. As for gold that is accompanied by sulphide minerals, that which is found at the Salobo and Pojuca copper deposits of Serra dos Carajas is representative. Besides, DOCEGEO has reported that the gold mined at the Lagoa Seca deposit of Serra das Andorinhas accompanies mineralized sulphide embedded in the contact of meta-pelitic rocks and rhyodacite of the Grao Para Group.

(2) Copper

Copper deposits are represented by the Salobo copper deposit and the Pojuca copper deposit embedded in the "Salobo-Pojuca Sequence" of the Grao Para Group, which is distributed in Serra dos Carajas. The Bahia copper deposit, which is under exploitation by DOCEGEO, is embedded in the Rio Fresco Formation.

The copper ore of the Salobo copper deposit mainly consists of bornite and chalcopyrite and is embedded in amphibolite-dominated schist. The deposit has been regarded as an exhalative volcanic sedimentary deposit. The Pojuca copper deposit is embedded in amphibolite and amphibole schist in the same sequence as that of the Salobo deposit and consists of chalcopyrite and bornite in disseminated and/or fracture-stringer shapes. The ore genesis of the deposit is considered to be volcanogenic. The Bahia ore deposit has been regarded as a sedimentary copper deposit syngenetically embedded in sedimentary rocks of the Rio Fresco Formation.

(3) Tin

Tin deposits are concentrated in the Rio Xingu area to the southwest of Serra dos Carajas. The first tin deposit in the area, accompanying the Velho Guilherme granite in Rio Branco, was discovered by IDESP in the 1970s. Following this discovery, the Mocambo ore deposit and the Sao Francisco ore deposit in southern Sao Felix do Xingu were discovered by PROMIX, and the Antonio Vicente ore deposit in northern Sao Felix do Xingu was discovered by the CVRD group. All tin mineralizations at these deposits are related to the intrusion of the Velho Guilherme type granite.

(4) Nickel

Both sulphide nickel and lateritic nickel are embedded in ultrabasic rocks. The nickel ore deposits in the area are represented by those of lateritic nickel type but economically viable sulphide nickel deposits have not been discovered yet.

The principal ore deposits are distributed in the south of Serra dos Carajas. The Vermelho, Puma, Onca and Jacare ore deposits are distributed from east to west in the southern side of Serra dos Carajas, and the Quatipuru ore deposit is located adjacent to Conceicao do Araguaia.

The Vermelho and Quatipuru ore deposits were discovered by CVRD/DOCEGEO, and the Puma, Onca and Jacare ore deposits were discovered by INCO. These are laterite nickel ore deposits.

(5) Manganese

The principal manganese ore deposits are distributed in and around Serra dos Carajas and are embedded in the Grao Para Group and the Rio Fresco Formation.

The Azul ore deposit, the largest deposit, is embedded in the pelitic sedimentary rocks of the Rio Fresco Formation distributed in the axial part of the Carajas synclinorium. The Buritirama ore deposit is embedded in the metasediment and metavolcanics of the Grao Para Group in Serra Buritirama. The ore shoots near the surface were formed by supergene enrichment of silica-carbonate manganese protore. The Sereno ore deposit in the Grao Para Group is located in Serra do Sereno in eastern Serra Pelada, and was also formed by supergene enrichment of silica-carbonate manganese protore. These deposits were all discovered by CVRD/DOCEGEO.

In addition, small scale mineral occurrences are also known in the Rio Fresco Formation of Serra dos Gradaus.

(6) Iron

Iron deposits are originated in the Carajas Iron Formation of the Grao Para Group, and are widely distributed in Serra dos Carajas and more than ten ore bodies have been discovered by CVRD.

The Carajas Iron Formation consists of jaspilite rocks (itabirite), and the iron ore deposits are large scale and high grade hematite deposits in supergene enrichment zones which were formed by weathering and silica leaching of itabirite.

Small scale iron ore deposits have also been discovered in the Grao Para Group in Serra Arqueada and Serra do Pium, and there are also some iron formations in Serra das Andorinhas, Serra dos Gradaus and Serra Inaja.

(7) Aluminium

Numerous bauxite ore deposits embedded mainly in Tertiary sedimentary rocks are distributed in the Amazon Region as a whole. The major deposits are concentrated in three areas: Trombetas, Almeirim and Paragominas.

In the Greater Carajas Program Area, a group of bauxite ore deposits are located in the Paragominas area. The major part of the ore deposits consists mainly of lateritic massive bauxite, and the upper part of the deposits is composed of mixed zones of lateritic alumina and ferruginous laterite.

As to other types, there are also such bauxite ore deposits that have been formed by aluminium enrichment caused by the lateralization of basic metavolcanics of the Grao Para Group in Serra dos Carajas.

Forty million tons of bauxite ore reserves have been discovered by CVRD/DOCEGEO in the vicinity of the "N5" iron ore deposit in Serra Norte.

5. Recommendations for Future Exploration Projects

The results of the study, from the viewpoint of future exploration possibilities, can be summarized into three topics, such as: 1) Major findings on the three areas (Inaja, Bacaja and Serra dos Gradaus); 2) Recommended future exploration projects; and, 3) Required survey items in Salobo and Pojuca Copper Deposits. The following is a summary of findings and recommendations which the Study Team points out.

5-1 Major Findings

The exploration of mineral resources in the PGC Area is most advanced in the Carajas Mountains (Serra dos Carajas) area and in the bauxite region of Paragominas and kaolin region of Rio Campim. In the former area and its vicinity, a number of deposits of different ore types have been found embedded in Grao Para Group and Rio Fresco Formation as well as in the granite and ultrabasic bodies that intrude into the former two geologic units.

Accordingly, an attempt was made to identify areas that exhibit similar geological characteristics to those of Serra dos Carajas on the basis of the analysis of the data and information related to the particular geology that embeds various types of ore deposit. Among other areas, the probability of the existence of mineral ore deposits is considered especially high in the following three areas:

(1) Inaja Area

In the Inaja area which covers the mountain range of Serra Inaja, Au (gold) is the only mineral resource currently mined at a small scale and no other mineral resoures have been discovered. The geological analysis as described in the previous chapter, however, revealed that the area has similar geological characteristics to those of Serra dos Carajas and, therefore, the probability of the existence of ore deposits such as those of Cu (copper), Ni (nickel) and Sn (tin) in addition to Au is considered very high in this area.

The geology of the Inaja area consists of Xingu Complex, Grao Para Group, Rio Fresco Formation and Gorotire Formation. In addition, two kinds of granite are widely distributed in these geologic units. The Grao Para Group in this particular area is intercalated with metabasic volcanics and iron formations and thereby resembles the rock facies of the Grao Para Group of Serra dos Carajas.

As shown in the interpretation map of Landsat images (Figure 4-5), Grao Para Group and Rio Fresco Formation are distributed in the N-S direction in and to the west of the mountain range of Serra Inaja. These geological strata exhibit a tendency to continue to the Serra dos Gradaus area. The analysis of airborne magnetic and radiometric surveys revealed that magnetic anomaly is distributed along Serra Inaja, indicating the existence of iron formations and metabasic volcanics of Grao Para Group. Furthermore, the distribution of circular intrusive bodies in three parts of the western edge of Serra Inaja corresponds to the distribution of low thorium (Th) areas as identified in the airborne radiometric survey, suggesting the probability of the intrusive bodies being alkaline intrusive rocks. Geochemical exploration results also indicated that there is the anomaly of Cu-Ni-Co along the Grao Para Group of Serra Inaja.

(2) Bacaja Area

No geological or geochemical data are available to make it possible to evaluate the potential of mineral resources in the Bacaja area in a comprehensive manner. It is known, however, that metabasic-amphibolite is distributed in and around the River (Rio) Xingu and that quartz veins accompanied by Au (gold) mineralization is distributed around the granite that intrudes into the rock body.

Our analysis of the Landsat images and geophysical surveys suggests that Grao Para Group is probably widely distributed in the Bacaja area. Further, the aeromagnetic analysis (see Plate III-11) indicates that magnetic anomaly of the same scale as that of Serra dos Carajas is widely distributed to the north of the NE-SW fault that cuts across Serra dos Carajas. As the distribution of magnetic anomaly seems to correspond to that of Grao Para Group, the probability of the existence of mineral ore deposits in this area is considered very high.

(3) Serra dos Gradaus Area

This area covers the mountain ranges of Serra dos Gradaus, Serra das Seringa and Serra das Andorinhas. In Serra dos Andorinhas, DOCEGEO's exploration discovered the mineralization of Au (gold), Pb (lead) and Cu (copper), in addition to iron formation. At Cumaru to the south of Serra dos Gradaus, Au is mined by diggers (garimpeiros). According to DOCEGEO, the metabasic volcanics distributed in Serra dos Gradaus and Serra das Andorinhas are considered to consist "greenstone belt" sequences incorporated in Xingu Complex.

However, our analysis suggests that the "metabasic - volcanics sequence" seems to correspond to the Grao Para Group distributed in the Serra dos Carajas area. In addition, Rio Fresco Formation and numerous granite rock bodies are distributed in Serra dos Gradaus. It is therefore quite reasonable to assume the existence of Au, Cu, Fe (iron), Mn (manganese), Sn (tin) and other mineral resources in the area.

The granite of Serra das Seringa and Serra dos Gradaus is classified into the Carajas Granite type and has been considered to have no particular connection with Sn mineralization. However, the radiometric survey analysis revealed the distribution of a number of thorium anomalies of small scale around these granite bodies, in the same pattern as recognized in the area between Serra das Andorinhas and the east of Serra dos Carajas. Since it is considered that these thorium anomalies suggest the existence of the granite type known as "Velho Guilherme Granite" which accompanies Sn mineralization, the probability of the existence of Sn ore deposits is particularly high in the Serra dos Gradaus area.

5-2 Future Exploration Project in the Greater Carajas Program Area

In general, a particular method of exploration is chosen in view of the current state or stage of mineral exploration and of geological conditions as well as types and forms of ore deposit assumed to exist in the area concerned. From these viewpoints, the Greater Carajas Program Area (the PGC Area) can be described as follows:

- Mineral exploration in the area is at the stage of reconnaissance and regional geological survey.

- Grao Para Group and Rio Fresco Formation as well as the granite and ultrabasic bodies that intrude into the former two geologic units, provide for the major geological environment for mineral resources in the Precambrian section of the Area.

- The major types and forms of mineral resources expected to exist in the PGC Area are copper ore deposits of the impregnate type, placer deposits of gold and tin, lateristic deposits of nickel and manganese, bauxite and rare earth mineral deposits associated with the intrusive rocks. Other potential deposits are copper and nickel ores of the massive sulphide type, zinc ore, wolframite of vein and alluvium types, asbestos in the ultrabasic bodies, as well as minerals of the platinum group.

As pointed out in the outset, three areas (Inaja, Bacaja and Serra dos Gradaus) are some of the most promising areas in which major efforts shall be concentrated, besides the Serra dos Carajas itself. Other areas such as the Precambrian section at the Maranhao - Para states border and the Araguaia river region, both in Para and Goias states, not studied in detail in this report, must be not overlooked. Although some geological and geochemical surveys have been carried out in and around these areas, these surveys actually covered only a small portion of the areas under discussion and the data obtained in such surveys are not necessarily reliable. As a result, not much is known at present as to geological and geochemical characteristics of the three areas. Therefore and in due consideration of economic efficiency, it is recommended that a super-regional geochemical and geological survey covering all the three areas should be carried out. As described hereinunder, this super-regional survey aims to clarify geological characteristics, geologic units and structural sequences or anomaly distribution of a particular mineral or minerals and to define the most appropriate exploration method for the exploration sites to be pin-pointed by the super-regional survey.

5-2-1 Recommnded Project

Figure 5-1 shows the area of approximately 100,000 km2 including Inaja, Bacaja and Serra dos Gradaus for which the super-regional geological and geochemical survey is recommended. The project being recommended will prove to be highly important to formulate a comprehensive mineral resources development program for the western side of the PGC Area since the probability of various kinds of minerals (e.g., Cu, Au and Sn) being discovered in the proposed project area is considerably high. The following is an outline of the proposed project:

(1) Area: Approximately 100,000 km^2

(2) Objective

To carry out a series of geochemical studies of stream sediment samples as well as geological surveys of the area and to compile a comprehensive geological map and a distribution map of metal elements.

(3) Basic Map: 1:250,000

Compilation of a new drainage map based on the radar images of RADAM Project is required since the existing drainage map compiled by DNPM is so roughly drawn that it cannot be used for the proposed project.

(4) Survey Team and Duration of Project

A total of twelve (12) geologists and geochemists organized into five field survey teams can work on the project for the duration of three to four years.

(5) Geological Survey

Compilation of Geological Maps at scales of 1:250,000 and 1:1,000,000.
Collection of rock samples for thin section: 180 samples.
Collection of ore samples for polished section: 100 samples.
Chemical analysis of rock samples: 110 sampls.
Chemimal analysis of ore samples: 80 samples.
Measurement of geologic ages of samples: 80 samples.

(6) Geochemical Survey

(a) Sampling

Stream Sediment: 5,000 samples (Sampling Density: 15-20 km2/sample)
Panning Samples: 1,000 samples.

Sampling points shall be selected on the new drainage map (1:250,000) at the sampling density of 15 - 20 km2/sample. For those areas outside the drainage basin, panning samples shall be used. Although a higher sampling density is generally preferred for the purposes of geochemical survey, the above density is considered reasonable in view of the scales of geologic units and ore deposits expected to exist in the PGC Area. In addition, the area is not quite accessible to permit sampling at higher density. It is expected that this regional geochemical survey will effectively reveal target areas in which more detailed surveys may be carried out.

(b) Geochemical Analysis

Stream Sediment: Elements to be analysed include Au, Cu, Zn, Sn, Ni, Co, Cr (and rare elements, if necessary)
Panning Samples: Semi-quantitative analysis for 30 elements and quantitative measurement of heavy minerals

5-2-2 Exploration Method for Each Area

Under the current circumstances, the following methods and contents of exploration are considered most appropriate for each of the three areas - Inaja, Bacaja and Serra dos Gradaus, although these are to be re-defined and refined in detail in respect to the scope, contents and methods of exploration on the basis of the super-regional geochemical and geological survey discussed above.

(1) Inaja Area

Geological, geochemical and geophysical methods are recommended as follows:

(a) Geological Survey: Major purposes of this survey are to identify rock formations and to confirm rock types of the circular intrusive bodies.

(b) Geochemical Survey: This survey is required since existing geochemical data are insufficient. The survey shall cover such elements as Au, Sn, rare earth, Cu, Ni, Cr, Co.

(c) Geophysical Survey: Airborne magnetic and radiometric surveys are required for the area west of longitude 51° west.

(2) Bacaja Area

The super-regional survey is a prerequisite for the compilation of a more accurate geological map and for the delineation of anomaly areas.

(3) Serra dos Gradaus Area

The super-regional survey is required to define geological stratigraphy of the area and to confirm the existence of Velho Guilherme Granite.

5-3 Required Survey Items in Salobo and Pojuca Copper Deposits

As a result of initial exploration surveys carried out by the Brazilian side at the Salobo and Pojuca ore deposits, it is known that the principal mineral composition at the former ore deposit is bornite-chalcocite-magnetite while it is chalcopyrite-pyrite-bornite-magnetite at the latter ore deposit. In addition, it is also known that the two deposits are different in their ore formations. In due consideration of these differences and on the basis of our own analysis of the survey results, a series of preliminary studies as outlined below are proposed for the formulation of a comprehensive development program for the two copper deposits;

(1) More precise ore reserve calculation and investigation of the formation and mineral composition of the ore bodies. Supplemental trial mining and pit prospecting may be carried out.

(2) Selection of the most effective and economical mining method. The ore bodies generally dip steeply and open-pit mining is quite difficult. In addition, ore-containing veins and unproductive veins are complexly intermingled. Therefore, a careful study of a mining plan and the selection of the most appropriate mining method are quite important to maintain ore quality.

(3) Selection of the most effective ore dressing method. A study of ore dressing methods to select the most effective method is indispensable. In particular, adverse effects of clay minerals produced by the alteration of basic and ultrabasic rocks to ore dressing shall be taken into consideration.

(4) Research related to smelting methods. In particular, investigation of the degree of sulfur recovery when the Pojuca ore consisted mainly of chalcopyrite and pyrite is mixed with the Salobo ore consisted mainly of bornite and chalcocite, is required.

(5) Preliminary evaluation of economic viability. The first substantial data for the evaluation of economic viability of the two deposits are obtained in the studies related to the above items (1) to (4). An overall economic analysis shall then be performed on the basis of rough engineering and structural designs related to mining, dressing, smelting, etc., in due consideration of construction and operation costs as well as current and future metal prices.

(6) Other items to be considered are:

(a) Mining plan in terms of the optimum amount of mining

(b) Design of underground mining pits

(c) Selection of machinery

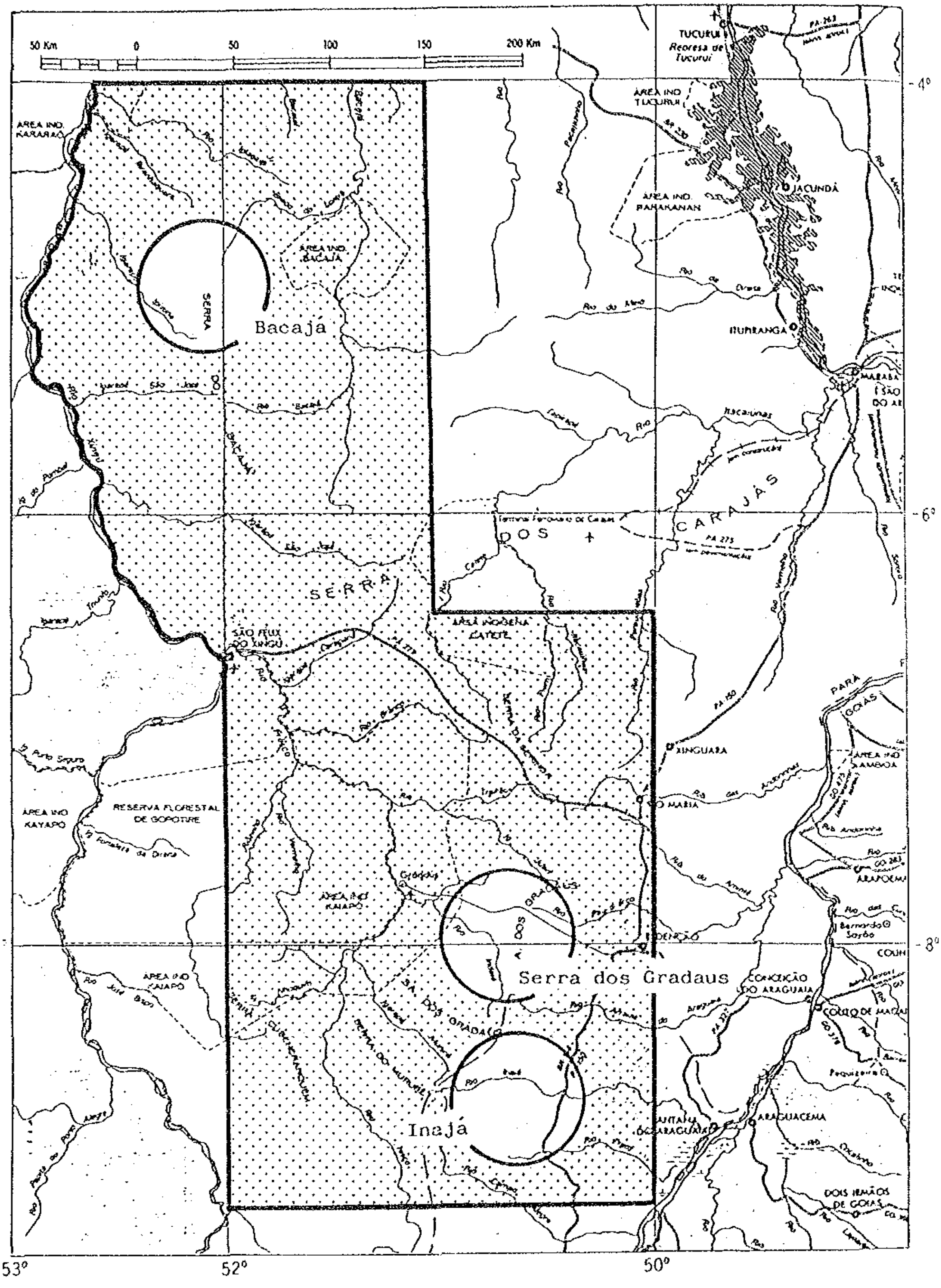
(d) Production control plan

(e) Design of dressing and tailings disposal facilities

(f) Design of supplementary facilities

(g) Overall development plan

Figure 5-1 The Recommended Area of Regional Geological and Geochemical Survey



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APPENDICES

APPENDIX 1

Summary of the Projects related to Geological Survey

Reference No. G-1

1. Name of Project: "Reconhecimento Geologico Preliminar da Area do Projeto Grao Para"

2. Executing Organization: DNPM

3. Duration: September 4 - October 24, 1968

4. Objective: To carry out a regional geological survey for the purpose of mineral exploration.

5. Covered Area: 40,000 km^2.

6. Methods: Geological and pit surveys at the kaolinite horizon.

7. Given Data: One report and reconnaissance geological maps (1:500,000), as well as other documents related to the study of geological structure and the investigation of various mineral occurrences in the project area.

8. Results of Geological Survey:
   - Precambrian geological stratigraphy was established.
   - Geological structure of the area was clarified.

9. Utilized Data: None.

Reference No. G-2

1. Name of Project: "Projeto Estudo Global dos Recursos Minerais da Bacia Sedimentar do Parnaiba"

2. Executing Organizations: DNPM/CPRM

3. Duration: April 1, 1975 - May 30, 1978

4. Objectives: To establish geological stratigraphy; to clarify the relationship between geological structure, rock facies and ore deposits; and to evaluate the potential of the ore deposits.

5. Covered Area: 810,000 km^2. Refer to the index map (Plate III-1).

6. Methods: Geological surveys (two geologists x nine parties, 20 - 45 days), chemical analysis (rocks and stream sediments), and aerial photo (1:60,000) and radar image (1:250,000) analyses.

7. Given Data: 16 reports with geological maps (1:500,000 and 1:1,000,000), metallogenic epoch, chemical analysis results, sample location maps and others.

8. Results of Geological Survey:
Analyses of geological stratigraphy, geological structure and ore deposits of the Parnaiba basin were carried out.

9. Utilized Data: Some geological maps.

Reference No. G-3

1. Name of Project: "Projeto Norte Da Amazonia, Dominio Oiapoque-Jari"

2. Executing Organizations: DNPM/CPRM

3. Duration: 1974

4. Objectives: To carry out geological mapping (1:250,000 and 1:500,000), the investigation of mineralised zones, and the extraction of the areas where a detailed survey is required on the basis of geochemical exploration results.

5. Covered Area: Refer to the index map (Phase III-1).

6. Methods: Interpretation of radar images (1:250,000) and aerial photos, ground checking surveys and geochemical exploration as well as the examination of references.

7. Given Data: Seven reports with geological maps (1:500,000).

8. Results of Geological Survey:
Documents (No. III-A and No. IV) were obtained to describe parts of the geology of the Greater Carajas Programe Area with particular emphasis on the formations younger than those of the Cretaceous period.

9. Utilized Data: None.

Reference No. G-4

1. Name of Project: "Projeto Integracao Geologico - Geofisica Sul Do Para"

2. Executing Organizations: DNPM/CPRM

3. Duration: April 1978 - June 1979

4. Objectives: To compile geological maps (1:500,000), and to check anomalies uncovered in a geophysical exploration (a magnetic survey).

5. Covered Area: 182,000 km^2. Refer to the index map (Phase III-1).

6. Methods: Photo interpretation and ground checking radiometric prospecting.

7. Given Data: Six reports.

8. Results of Geological Survey:
   In the geophysical exploration, the Amazon synclinorium and the Paraguai-Araguaia geosyncline were clarified.
   Stratigraphic geological structure and ore deposits of the area were studied.

9. Utilized Data: Geological maps.

Reference No. G-5

1. Name of Project: "Projeto Gurupi"

2. Executing Organizations: DNPM/CPRM

3. Duration: May 21, 1970 - October 21, 1974

4. Objectives: To undertake an interpretation of radar images (1: 250,000) and geological surveys along rivers; to extract areas in which a semi-detailed survey is to be carried out (1:100,000) and to investigate mineralized zones and to carry out a survey of Travira Island and Pirocana Plain in search for phosphate ore deposits as well as to evaluate the economic potential of the deposits by means of chemical exploration of the Mico Norte Basin.

5. Covered Area: 85,000 km^2. Refer to the index map (Plate III-1).

6. Methods: The examination of references, photogeological analysis of a radar image (1:250,000) and geological reconnaissance surveys along rivers.

7. Given Data: Three reports with geological maps (1:500,000 and 1:250,000), distribution maps of mineralized zones, sample location maps and chemical exploration results.

8. Results of Geological Survey:
   A study of regional geological stratigraphy and geological succession was carried out. In the study, the combination of NW-SE and NE-SW systems was clarified.
   Ore deposits: the survey included the exploration of limestone, phosphate, Au and Mn. Au is presumably hydrothermal since it is recognized in quartz veins. There is no indication that the granite in the Basal Complex was directly related to mineralization.

9. Utilized Data: The date related to the northeastern geology were used.

Reference No. G-6

1. Name of Project: "Projeto Gurupi (Etape II)"

2. Executing Organizations: DNPM/CPRM

3. Duration: 1976 - 1977

4. Objectives: To carry out geological mapping (1:100,000), extraction of the areas of phosphate deposit, limestone and others, and geochemical exploration of stream sediment, panning samples, soil and rocks.

5. Covered Area: 21,500 km^2. Refer to the index map (Plate III-1).

6. Methods: The interpretation of aerial photos and radar images, and geochemical and geological surveys.

7. Given Data: One report, geological maps and geochemical maps (1:500,000).

8. Results of Geological Survey:
   The South American cycle, Velhas cycle and Paraguaca cycle were studied and the relationship between geochemical results and alkaline rocks were interpreted. The metamorphism in the area was also studied.

9. Utilized Data: None

Reference No. G-7

1. Name of Project: "Projeto Araguaia"

2. Executing Organizations: DNPM/PROSPEC

3. Duration: 1954 - 1962

4. Objectives: To obtain information related to geological stratigraphy and tectonic, and to delineate ore depposits.

5. Covered Area: 423,000 km^2. Refer to the index map (Plate III-1).

6. Method: Photo interpretation (1:45,000).

7. Given Data: Some references without maps.

8. Results of Geological Survey:
   A geological stratigraphic analysis was Carried out and the area where ore deposits are assumed to exist was identified.

9. Utilized Data: None

Reference No. G-8

1. Name of Project: "Projeto Argila-Belem"

2. Executing Organizations: DNPM/CPRM

3. Duration: January 1970 - December 1971

4. Objectives: To carry out geological mapping for the classification of mineralized zones, especially the clay ore deposits for the ceramics or the glass industries.

5. Covered Area: 33,450 km^2. Refer to the index map (Plate III-1).

6. Methods: A geological survey, and the examination of references.

7. Given Data: One report and geological maps (1:500,000).

8. Results of Geological Survey:
   The clarification of Precambrian geological succession and the examination of the types of ore deposits were carried out.

9. Utilized Data: Some references.

Reference No. G-9

1. Name of Project: "Projeto Radambrasil Levantamento de Recursos Naturais Vol. 22 Folha, SC. 22 Tocantins"

2. Executing Organization: DNPM

3. Duration: 1972 - 1976, publication in 1981

4. Objectives: To compile geologic and topographic maps as well as rock distribution, vegetation and land utilization maps.

5. Covered Area: 290,950 km^2. Reger to the index map (Plate III-1).

6. Method: The compilation of existing data including radar images, aerial photos and ground checking survey results.

7. Given Data: One report with six maps.

8. Results of Geological Survey:
   The classification of Precambrian geological succesion was carried out. The areas where ore deposits (Fe, Mn, Ni, Au and Ln) are assumed to exist were identified.

9. Utilized Data: Geological maps.

Reference No. G-10

1. Name of Project: "Projeto Mapa de Previsao da Provincia Estanifera do Sul Do Para"

2. Executing Organization: DNPM

3. Duration: 1973

4. Objectives: To carry out a tin ore deposit survey and a survey of the granite ring structure.

5. Covered Area: 164,800 km^2. Refer to the index map (Plate III-1).

6. Method: The extraction of granite (Velho Guilherme Granite) by means of a radar image.

7. Given Data: One report with geological maps (1:1,000,000).

8. Results of Geological Survey:
   - The granite assumed to be related to Sn mineralization consists of 20 circular bodies of Velho Guilherme Granite. The Sn mineralized zone extends to the direction of ENE-WSW - E-W.
   - The estimated researves of cassiterite in the southern part of the state of Para amount to a total of 70,000 tons.
   - 200 tons in 1973 and 300 tons in 1974 are estimated, amounting to about 7% of the Brazil's total Sn production.
   - The types of the ore deposits in Serra do Velho Guilherme, Mocambo and Sao Francisco were studied.

9. Utilized Data: Geological maps.

Reference No. G-11

1. Name of Project: "Geologia Regional da Procincia Mineral de Carajas"

2. Executing Organization: DOCEGEO

3. Duration: 1982

4. Objective: To conduct a mineral exploration.

5. Covered Area: Refer to the index map (Plate III-1).

6. Methods: Geological and geochemical surveys.

7. Given Data: Geological maps (1:1,000,000).

8. Results of Geological Survey: Unavailable.

9. Utilized Data: Geological maps.

<u>Reference No. G-12</u>

1. Name of Project: "Projeto Estudo dos Garimpos Brasileiros Area Cumaru"

2. Executing Organizations: DNPM/CPRM

3. Duration: 1981 - 1982

4. Objective: To investigate the activity of garimpos.

5. Covered Area: Refer to the index map (Plate III-1).

6. Methods: N.A.

7. Given Data: One report with geological maps (1:45,000).

8. Result of Geological Survey: N.A.

9. Utilized Data: None.

<u>Reference No. G-13</u>

1. Name of Project: "Projeto Maraba"

2. Executing Organizations: DNPM/CPRM

3. Duration: June 1970 - 1972

4. Objectives: To carry out geological mapping (1:250,000), geochemical exploration of river sediment and soil and a survey of mineralized zones. These are all for the evaluation of the geology and the potential of ore deposits.

5. Covered Area: 72,600 km^2. Refer to the attached map (5°S-7°S and 48° W-51°W).

6. Methods: Photo analysis (1:45,000; 1:60,000; 1:100,000 and 1:250,000), geological surveys along rivers and a geochemical exploration.

7. Given Data: Nine reports.

8. Result of Geological Survey:
   The Precambrian geological stratigraphy and the Maranhao Basin sequence were classified.

9. Utilized Data: Some references.

Reference No. G-14

1. Name of Project: "Projeto Rio Chiche"

2. Executing Organizations: DNPM/CPRM

3. Duration: 1979 - 1980

4. Objective: To clarify Au and Sn ore deposit potentials.

5. Covered Area: Refer to the attached map (Plate III-1).

6. Methods: Geological and geochemical surveys and aerial photo interpretation.

7. Given Data: Two reports.

8. Result of Geological Survey:
   From the results of the survey over the Au and Sn mineralized zones, it was revealed that these ore deposits are imbedded in polymetamorphic rocks.

9. Utilized Data: None.

Reference No. G-15

1. Name of Project: "Projeto Materiais de Construcao Tucurui - Carajas"

2. Executing Organizations: DNPM/CPRM

3. Duration: 1977

4. Objective: To investigate constraction materials such as sand, clay, limestone and gravel.

5. Covered Area: Refer to the attached map (Plate III-1).

6. Method: Photo interpretation.

7. Given Data: Five reports.

8. Results of Geological Survey: N.A.

9. Utilized Data: None.

Reference No. G-16

1. Name of Project: "Projeto Transamazonica"

2. Executing Organizations: DNPM/CPRM

3. Duration: 1970 - 1974

4. Objective: To undertake a reconnaissance geological survey along the Tansamazonica road.

5. Covered Area: 1,180 km. Refer to the attached map (Plate III-1).

6. Methods: A geological survey and photo interpretation.

7. Given Data: One report.

8. Result of Geological Survey:
   The sedimentary rocks of the Tocantins Group and the Maranhao Amazonas Basin were classified.

9. Utilized Data: None.

Reference No. G-17

1. Name of Project: "Projeto Bacia do Araguaia Para"

2. Executing Organization: IDESP

3. Duration: 1974

4. Objectives: To understand the geological structure and history and to examine ore deposit potentials.

5. Covered Area: Longitude 50°W - Rio Araguaia.

6. Method: Photo interpretation.

7. Given Data: One report including some geological maps (1:1,000,000).

8. Results of Geological Survey:
   The directional quality of the NW-SE system (the eastern area) of the Brazilian orogenic cycle and that of the E-W system (the western area) of Uruacuano folds as well as the N-S system structure which devides the former two were clarified. It was also clarified that the probability of the existence of ore deposits such as Fe, Ni, Cr, Cu, Au, Sn, Mn and diamond is high. Mi and Cr exist in the form of a serpentine belt.

9. Utilized Data: None.

Reference No. G-18

1. Name of Project: "Pragrama de Pesquisas de Carvao Mineral Na Bacia do Rio Fresco, Alluente do Xingu, Estado do Para"

2. Executing Organizations: CPCAN/IDZSP

3. Duration: 1970 - 1971

4. Objective: To undertake a survey of coal ore deposits.

5. Covered Area: 7°S - 8°S and 50°W - 52°W, 6°30'S - 7°S and 51°30'W - 52°W.

6. Methods: A geological survey and aerial photo interpretaiton.

7. Given Data: Vol.II "texto" (two geological maps could not be obtained)
   Vol.III "texto" (drilling process schedule)

8. Result of Geological Survey:
   The existence of the Grao Para Group including iron formations and various granite was revealed.

9. Utilized Data: None.

Reference No. G-19

1. Name of Project: "Projeto Calcario"

2. Executing Organization: IDESP

3. Duration: September 1970 - February 1972

4. Objective: To undertake a survey of the limestone for cement.

5. Covered Area: 5 areas (3 areas are included in the Greater Carajas Progame Area).

6. Methods: Geological survey and photo interpretation.

7. Given Data: One report (some geological maps are included).

8. Result of Geological Survey:
   No promising district was indicated in the Carajas area.

9. Utilized Data: None.

Reference No. G-20

1. Name of Project: "Projeto Cobre Para"

2. Executing Organizations: DNPM/PROSPEC

3. Duration: 1970

4. Objectives: To undertake geological mapping and geochemical exploration of Cu, Pb, As, Zn and Ag.

5. Covered Area: "Etape I" - 6°30' - 7°S
   51°51 - 52°30'W
   "Etape II"- 6°38' - 7°S
   51°55 - 52°33'W

6. Methods: A geological survey, rock and soil sampling and photo analysis.

7. Given Data: Reports with geological maps.

8. Result of Geological Survey:
   It was found that Cu, Pb and Fe ore deposits are distributed in the Tocandeire Formation, while Mn ore deposit is distributed in the Rio Fresco Formation.

9. Utilized Date: None.

Reference No. G-21

1. Name of Project: "Projeto Balsas"

2. Executing Organizations: DNPM/UFPa

3. Duration: 1977

4. Objectives: To undertake geological mapping, and the training of the geology students at UFPa.

5. Covered Area: Refer to the attached map (Plate III-1).

6. Methods: A geological survey and photo analysis (1:25,000).

7. Given Data: Reports with geological maps (1:100,000), a columnar graph (1:500) and cross sections (1:100,000 and 1:5,000).

8. Result of Geological Survey:
   The geological stratigraphy from the Permian to Jurassic periods was classified.

9. Utilized Data: None.

Reference No. G-22

1. Name of Project: "Projeto Sulfetos de Altamira - Itaituba"

2. Executing Organizations: DNPM/CPRM

3. Duration: 1974 - 1977

4. Objectives: To undertake geological mapping (1:100,000), and to delineate detailed survey areas. To study the mineral potential of the nonferrous metal ore deposit in the Paleozoic formation along the Transamazonica road.

5. Covered Area: 15,000 km^2. Refer to the attached map (Plate III-1).

6. Methods: Geochemical exploration (river sediment and panning samples) radioactive prospecting and a survey of mineralized zones.

7. Given Data: Seven reports with Vol. I "texto" including geological maps (1:500,000).

8. Result of Geological Survey:
   In the Bacaja area, Au-qtz vein is embedded in the Tres Palmeitos Formation - Grao Para Group (low metamorphic grade basic rocks). The Tres Palmeitos Formation is assumed to extend to the WNW-ESE direction from Serra dos Carajas in the Bacaja area. In addition, mineral potentials of Fe, Mn and Sn are also found high.

9. Utilized Data: None.

Reference No. G-23

1. Name of Project: "Projeto Xingu-Araguaia Area Gradaus-Nova Olinda"

2. Executing Organizations: SUDAM/CPRM

3. Duration: 1972/3 - 1975

4. Objectives: To carry out a geological reconnaissance survey of 100,000 km^2 (1:250,000), an aerial magnetic exploration, a geochemical exploration (river bed sediment and panning samples), a mineralized zone survey and the extraction of the areas where a detailed survey is to be carried out.

5. Covered Area: 14,500 km^2. Refer to the attached map (Plate III-1).

6. Methods: Photo (1:45,000) and radar image (1:250,000) analysis, geological surveys along rivers and geochemical and geophysical exploration.

7. Given Data: Three reports.

8. Result of Geological Survey:
   It was revealed that gold mineralization is related to the hydrothermal activity of ultra-basic rocks, while tin mineralization is related to the granite of the Velho Guilherme type.

9. Utilized Data: None.

Reference No. G-24

1. Name of Project: "Relatorio Final de Pesquisa Setor Camoai"

2. Executing Organizations: RIODOCE/DOCEGEO

3. Duration: 1974 - 1977

4. Objective: Al prospecting.

5. Covered Area: Almost the same as the area shown in the attached map (41,425 ha).

6. Methods: Radar image analysis and geological survey as well as pit and chemical analysis.

7. Given Data: Vol. I, "Texto" with geological maps (1:250,000), but without maps of mineralized zones.
   Vol. II "Mapas, Perfis Geologicos e Tabelas de Cubagen"
   Vol. III "Perfis de Pogos"
   Vol. IV "Tabelas de Analises Quimicas"

8. Result of Geological Survey:
   A total of 152,218,400 tons of mineral ore reserves is estimated.

9. Utilized Data: None.

Reference No. G-25

1. Name of Project: "Relatorio Final de Pesquisa Serra das Andorinhas"

2. Executing Organizations: CVRD/DOCEGEO

3. Duration: June 1973 - February 1977

4. Objective: To carry out a massive sulfide and Au exploration.

5. Covered Area: Remains unclarified but approximately as follows:
   49°35' - 50°15'W
   7°05' - 7°30'S

6. Methods: Regional geological and geochemical (soil and stream sediment) exploration and an airborne geophysical survey.

7. Given Data: Vol. I "Texto"
   Vol. II 20 chemical exploration maps
   30 geophysical "
   Vol. III Analysis results

8. Results of Geological Survey:
   Geological stratigraphy of the concerned area was clarified.
   Ore deposits: Pb, Zn and Au ore deposits (stratiform-stratabound) were found to exist in the Grao Para Group.

9. Utilized Data: None.

<u>Reference No. G-26</u>

1. Name of Project: "Relatorio Final de Pesquisa Projeto Aluminio Serra dos Carajas"

2. Executing Organizations: RIODOCE/DOCEGEO

3. Duration: January 1975 - September 1976

4. Objective: To evaluate the Al ore deposit of "Plato N-5" in the northern part of N-5.

5. Covered Area: Refer to the attached map (Plate III-1).

6. Methods: Geological mapping, pit bowling and geochemical analysis.

7. Given Data: Four reports.

8. Result of Geological Survey: Unavailable.

9. Utilized Data: None.

<u>Reference No. G-27</u>

1. Name of Project: "Projeto Mapas Metalogeneticos e de Previsao de Recursos Minerais, Folha"
   SB. 22-X-C, Rio Itacaiunas

SB. 22-X-D, Maraba
SB. 22-Z-A, Rio Parau a Pebas

2. Executing Organizations: DNPM/CPRM

3. Duration: 1983

4. Objective: To compile metalogenic maps.

5. Covered Area: SB. 22-X-C, Rio Itacaiunas.

6. Methods: A geological survey and the interpretation of aerial photos and radar images.

7. Given Data: Vol. I "Texto e mapas"
   Ore deposits maps (1:250,000) and mineral resource forecast maps.
   Vol. II "Mapas de servicos"

8. Results of Geological Survey:
   Geological mapping and the mapping of accurate locations of existing ore deposits were carried out.

9. Utilized Data: None.

Reference No. G-28

1. Name of Project: "Projeto Prospecgao de Carvao Energetico Nas Areas de Ocorrencia da Formacao Rio Fresco"

2. Executing Organizations: DNPM/CPRM

3. Duration: 1980

4. Objective: To prospect coal seams in the Rio Fresco Formation.

5. Covered Area: 1,863 km^2. Reger to the atached map (Plate III-1).

6. Methods: Photo interpretation (on-the-spot check), geophysical exploration (seismic exploration, electric resistivity) and drilling.

7. Given Data: One report with geochemical maps (1:100,000) and sample location maps (1:100,000).

8. Results of Geological Survey:
   - The relationshiip between the greenstone belt and Au ore deposit was studied.
   - Fe, Al, Cu, Ni and Sn mineralized zones were identified.

9. Utilized Data: Some references in respect to the relationship between the greenstone and Au in the Inaja area.

Reference No. G-29

1. Name of Project: "Projeto Carolina"

2. Executing Organizations: DNPM/UFPa

3. Duration: 1974 - 1979

4. Objectives: To undertake geological mapping (1:100,000) and the training of the geology students studying at UFPa.

5. Covered Area: Refer to the attached map.

6. Methods: Photo interpretation (1:60,000), a geological survey and mapping (1:100,000) and analysis and interpretation of rock flakes and sediment.

7. Given Data: One report with geological maps (1:100,000). The analysis of Lm, Gp and atapulgite mineralized zones.

8. Results of Geological survey:
   - The distribution of geologic units was clarified as a result of the establishment of geological stratigraphy.
   - The characteristics of each stratum were clarified based on the sedimentological study.

9. Utilized Data: None.

Reference No. G-30

1. Name of Project: "Projecto Xambioa-Vanderlandia"

2. Executing Organizations: DNPM/UFPa

3. Duraton: 1974 - 1978

4. Objectives: To carry out basic geological mapping (1:100,000), a study of stratigraphic correration and training of the geology students at UFPa.

5. Covered Area: 1,500 km^2. Refer to the attached map (Plate III-1).

6. Methods: Aerial photo analysis (1:45,000), a geological survey, a structural analysis (Wulff's net, rose diagram) and an analysis of metamorphism for the compilation of geological maps (1:100,000).

7. Given Data: One report, a geological map (1:100,000), and a columnar map (1:500).

8. Results of Geological Survey:
The Paraguai-Araguaia orogenic belt and the geological structure of the Parnaiba Basin were clarified.

9. Utilized Data: None.

Reference No. G-31

1. Name of Project: "Projeto Guarai-Conceicao"

2. Executing Organizations: DNPM/UFPa

3. Duration: 1975 - 1976

4. Objectives: Geological mapping, and the training of the students learning about the field survey.

5. Covered Area: 2,700 km^2. Refer to the attached map (Plate III-1).

6. Methods: Interpretation of the aerial photo (1:45,000), radar images and the geological survey by RADAM.

7. Given Data: One report with geological maps (1:100,000).

8. Result of Geological Survey:
The geological stratigraphy of the area was established.

9. Utilized Data: The data related to the Tocantins-Araguaia area were used.

Reference No. G-32

1. Name of Project: "Relatorio de Pesquisa de Mineiro de Ferro 1972 Distrito Ferrifero da Serra dos Carajas"

2. Executing Organization: CVRD

3. Duration: 1969 - 1972

4. Objective: To evaluate Serra dos Carajas ore deposits (especially to estimate iron ore reserves and to prepare for the exploitation).

5. Covered Area: Refer to the attached map (160,000 ha).

6. Methods: Geological reconnaissance and detailed surveys and geophysical exploration.

7. Given Data: Vol. I "Texto"
II 119 diagrams

III Bowling process
IV Chemical analysis results
V Drilling section

8. Result of Geological Survey:
   - A total reserves of 17,884,945 tons of 66.1% Fe was estimated to exist.

9. Utilized Data: None.

Reference No. G-33

1. Name of Project: "Relatorio de Pesquisa de Cassiterita no Alto Rio Branco"

2. Executing Organization: PROMIX (PRODUTORA DE MINERAOS XINGU S/A)

3. Duration: 1973

4. Objectives: To undertake geological mapping and the estimation of Sn ore reserves (old alluvial deposits are is also included).

5. Covered Area: Refer to the attached map (Plate III-1).

6. Method: Reconnaissance and detailed geological surveys.

7. Given Data: One report and 11 geological maps.

8. Results of Geological Survey:
   The total Sn ore reserve was estimated at 676,563 kg.

9. Utilized Data: None.

APPENDIX 2

Summary of the Projects related to Geochemical Survey

Reference No. C-1

1. Name of Project: "Projeto Gurupi"

2. Executing Organizations: DNPM/CPRM

3. Duration: 1970 - 1975

4. Objectives: To undertake geological mapping, the exploration of raw materials for iron manufacturing phosphate menerals and nonferrous metals as well as a regional geochemical exploration.

5. Covered Area: 85,000 km^2. Refer to the index map (Plate III-3).

6. Methods: The analysis of radar images (1:100,000) and the regional geochemical exploration (analyzed elements: 29 elements; collected samples: 11 samples of soil, 69 panning samples, 232 samples of river bed sediment and 225 pieces of rock).

7. Given Data: Three reports with eight geological maps (1:250,000), five location maps (1:250,000) and three maps of chemical analysis results (1:500,000).

8. Result of Geochemical Survey:
Anomalies of Cu, Pb, Zn, Au, Fe, Ni, Mn and Sn are recognized in the area where the Grupi Group and the Basal Complex dominate. The former consists of sedimentary rocks such as precambrian slate and quartzite located in the center of the survey area. The latter principally consists of igneous rocks such as amphibolite and granodiorite.

9. Utilized Data: Geological maps (1:250,000) and geochemical analysis maps.

Reference No. C-2

1. Name of Project: "Projeto Gurupi Etapa II"

2. Executing Organizations: DNPM/CPRM

3. Duration: 1976 - 1977

4. Objectives: Geological mapping and the execution of a regional geochemical exploration.

5. Covered Area: 21,500 km^2. Refer to the index map (Plate III-3).

6. Methods: To carry out a geological survey and a regional geochemical exploration (analyzed elements: 30 elements; collected

samples: 117 samples of river bed sediment, 24 samples of soil, 164 pieces of rock, 51 panning samples; collection density: one sample per 5 - 10 km^2).

7. Given Data: Three reports with seven geological maps (1:100,000) and 13 maps of analysis results (1:100,000).

8. Results of Geochemical Survey:
Anomalies of Au, Mn and Al are confirmed in the survey area. Accordingly, the potentials of ore deposits such as those of limestone, kaoline and ilmenite are presumably high.

9. Utilized Data: Geological and other maps.

Reference No. C-3

1. Name of Project: "Projeto Norte da Da Amazonia"

2. Executing Organizations: DNPM/CPRM

3. Duration: 1972 - 1974

4. Objectives: To carry out geological mapping including the compilation of an ore deposit distribution map, and to undertake a regional geochemical exploration.

5. Covered Area: 85,000 km^2. Refer to the index map (Plate III-3).

6. Methods: Geological reconnaisance survey and regional geochemical exploration (analyzed elements: 30 elements; collected samples: 214 samples of soil, 24 pieces of rock, 1,901 samples of river bed sediment; collection density: one sample per approximately 40 km^2).

7. Given Data: Seven reports with two geological maps (1:2,500,000 and 1:1,000,000), 12 sample-collection location maps and (1:250,000) six maps of analysis results (1:2,500,000).

8. Results of Geochemical survey:
Samples were scarcely collected in the survey area. No anomaly has been recognized in the geochemical survey.

9. Utilized Data: None.

Reference No. C-4

1. Name of Project: "Projeto Geofisica Brasil"

2. Executing Organizations: DNPM/CANADA (GSC)

3. Duration: 1975 - 1979

4. Objective: To evaluate mineral resource potentials of the area from the central to the western part of Brazil.

5. Covered Area: 130,000 km^2 (63,000 km^2 in the survey area). Refer to the index map (Plate III-3).

6. Methods: Geological survey, geophysical prospecting and regional geochemical exploration (analyzed elements: 8 elements; collected samples: 3,197 samples of river bed sediment; collection density: one sample per 25 km^2 on the average).

7. Given Data: Two reports and 31 geological maps (1:100,000), 31 sample location maps (1:100,000), 93 maps of analysis results (1:100,000) and 31 maps of anomalous value distribution (1:100,000).

8. Results of Geochemical Survey:
   Numerous anomalies of Cu, Ni and Co are recognized in the east of Serra dos Carajas and in the basins of Rio Tocantins and Inaja. The anomalies distributed in the eastern Carajas and the Inaja area are related to the distribution of the Grao Para Group and the Rio Fresco Formation.

9. Utilized Data: 31 maps of anomaly value distribution (1:100,000).

<u>Reference No. C-5</u>

1. Name of Project: "Projeto Maraba"

2. Executing Organizations: CNPM/CPRM

3. Duration: 1970 - 1972

4. Objectives: To carry out geological mapping including the compilation of distribution maps of mineralization, and to undertake a regional geochemical exploration.

5. Covered Area: 72,600 km^2. Refer to the index map (Plate III-3).

6. Methods: Geological survey and regional geochemical exploration (analyzed elements: 17 elements; collected samples: 780 samples of river bed sediment, 64 samples of soil, 152 panning samples and 1,026 pieces of rock).

7. Given Data: Nine reports with four geological maps (1:250,000) and 16 maps of analysis results (1:250,000).

8. Results of Geochemical Survey:
   Sb, Au and Ag are distributed in the left bank area of Rio

Itacaiunas althought this area has been known for the distribution of Sb and Hg (Dorokhine et al., 1976). In addition, the area is important for Cr, Ni and Sb distribution. The mineralization of precious metals or that of either sulphide or sulphur oxide are assumed to have occurred in relation to basic-ultrabasic rocks enriched with the elements such as Cr, Ni and Sb.
The probability of the existence of Cu and Zn ore deposits embedded in volcanic and pyroclastic rocks of the Rio Parauapebas basin is considered high.

9. Utilized Data: 16 maps of analysis results (1:250,000).

Reference No. C-6

1. Name of Project: "Projeto Rio Chiche"

2. Executing Organizations: CNPM/CPRM

3. Duration: 1979 - 1980

4. Objectives: To carry out geological mapping and mapping of ore deposit distribution, economical evaluation of gold and silver ore deposits, and a regional geochemical exploration.

5. Covered Area: 54,000 km^2. Refer to the index map (Plate III-3). The geochemical exploration covered 12,840 km^2.

6. Methods: Photo analysis, geological survey, and regional geochemical exploration (analyzed elements; 23 elements, collected samples: 39 samples of soil, one piece of rock, 196 samples of river bed sediment and 118 panning samples).

7. Given Data: Two reports, three geological maps (1:250,000), three sample collection location maps (1:250,000), one map of analysis results and one ore deposit distribution map (1:1,000,000).

8. Results of Geochemical Survey:
Numerous anomalies of Au, Sn, Ni and others are recognized in the Rio Fresco basin where the geochemical exploration was carried out, suggesting a high probability of the existence of ore deposits.
The area is recommended for a detailed resource exploration including geophysical and geochemical studies.

9. Utilized Data: One map of analysis results.

Reference No. C-7

1. Name of Project: "Projeto Rio Xingu-Araguaia"

2. Executing Organizations: SUDAM/CPRM

3. Duration: 1972 - 1975

4. Objectives: To carry out geological mapping and to compile ore deposit distribution maps as well as to undertake an airborne magnetic prospecting and a regional geochemical exploration.

5. Covered Area: Approximately 100,000 km^2. The regional exploration covered 14,500 km^2.

6. Methods: Geological survey, radar image analysis (1:250,000), regional geochemical exploration (analyzed elements: 20 elements; collected samples: 339 samples of river bed sediment, 54 panning samples), and airborn magnetic prospecting.

7. Given Data: One report, one geological map (1:250,000), six sample collection location maps (1:100,000), one map of analysis results (1:250,000), some airborn magnetic prospecting maps, and some ore deposit distribution maps.

8. Results of Geochemical Survey:
Anomalies of Cr, Cu, Au and Ag are recognized. In particular, Cr and Au anomalies are numerously distributed in close association with basic-ultrabasic rocks.

9. Utilized Data: None.

Reference No. C-8

1. Name of Project: "Projeto do Cobre-Para"

2. Executing Organizations: DNPM/PROSPEC S.A.

3. Duration: 1968 - 1970

4. Objectives: To carry out geological mapping of the areas where anomalies are recognized and to undertake a detailed geochemical exploration to identify Cu and Pb ore deposits.

5. Covered Area: 48,400 km^2. Refer to the index map (Plate III-3). The detailed geochemical exploration covered 5 areas.

6. Methods: Geological survey, detailed geochemical exploration (analyzed elements: Cu, Pb, Zn and Ag; collected samples: 4,439 samples of soil and 96 pieces of rock).

7. Given Data: One report, one geological map (1:50,000), five sample collection location maps (1:10,000) five anomalous value distribution maps (1:10,000).

8. Results of Geochemical Survey:
   In the detailed geochemical exploration, more than 20 areas with Pb and Zn anomalies were extracted.

9. Utilized Data: One geological map (1:50,000).

Reference No. C-9

1. Name of Project: "Area Antonio Vicente"

2. Executing Organizations: CVRD/DOCEGEO

3. Duration: 1972 - 1978

4. Objectives: To explore Mn ore deposits in three areas whose mine claims are possessed by companies affiliated to Cia. Rio Doce, and to undertake a survey of igneous rock distribution areas in the Uatuma Group.

5. Covered Area: 540 km^2. Refer to the index map (Plate III-3).

6. Methods: Geological survey, detailed geochemical exploration (analyzed elements: Cu, Pb, Zn, Ni and Co; collected samples: 2,600 samples of river bed sediment, and one piece of rock per 2.6 km^2).

7. Given Data: One report with a geological map (1:250,000).

8. Results of Geochemical Survey:
   The existence of a high grade cassiterite ore deposit was revealed.

9. Utilized Data: None.

Reference No. C-10

1. Name of Project: "Projeto Cobre - Carajas"

2. Executing Organizations: CVRD/DOCEGEO

3. Duration: 1977 - 1981

4. Objective: To explore Cu ore deposits in the Salobo Basin.

5. Covered Area: Refer to the index map (Plate III-3) (20,000 ha.).

6. Methods: Geological survey, geophysical exploration, geochemical exploration (analyzed samples: 3,005 soil samples, 188 pieces of rock and 10 samples of river bed sediment and drilling exploration.

7. Given Data: One report, one geological map (1:1,000,000), geochemical exploration maps (1:10,000), maps of geophysical exploration results, etc.

8. Results of Geochemical Survey:
   A Cu ore deposit as described below was found:
   Scale: Water level 3.5 km
   Average thickness 200 m
   Depth 800 m
   Mineral quantity: 1,200 million tons
   Copper quantity: 10 million tons

9. Utilized Data: Maps of geochemical exploration results.

Reference No. C-11

1. Name of Project: "Projeto Serra Das Andrinhas"

2. Executing Organizations: CVRD/DOCEGEO

3. Duration: 1973

4. Objective: To explore ore deposits in Serra das Andrinhas.

5. Covered Area: Refer to the index map (Plate III-3) (10,000 ha.).

6. Methods: Geological survey, geophysical exploration, detailed geochemical exploration (analyzed elements: Cu, Pb, Zn and Au; collected samples: 28,800 samples of soil, 1,614 pieces of rock and river bed sediment samples).

7. Given Data: Two reports, four geological maps (1:250,000), geochemical maps (three at 1:100,000; 16 at 1:250,000; and two at 1:50,000) and several geophysical exploration maps.

8. Results of Geochemical Survey:
   A significant distribution of Pb and Zn anomalies was discovered in the areas in which the so-called "Unidade Sedimentar Superior" is predominant. Au anomalies were recognized in the areas where the so-called "Unidade Volcanica Inferior" is predominant.

9. Utilized Data: Geochemical exploration maps.

Reference No. 12

1. Name of Project: "Projeto Sao Felix do Xingu"

2. Executing Organizations: DNPM/CPRM

3. Duration: 1969 - 1971

4. Objective: To explore Pb ore deposits in the Sao Felix do Xingu area.

5. Covered Area: 160 km^2. Refer to the index map (Plate III-3).

6. Methods: Geological survey, detailed geochemical exploration (analyzed elements: Cu, Pb, Zn, Ni and Mn; collected samples: 407 samples of soil, six pieces of rock), as well as geophysical and drilling exploration.

7. Given Data: One report, one geological map (1:20,000), four geochemical exploration maps (1:10,000) and 40 geophysical exploration maps.

8. Result of Geochemical Survey:
Results of the geological survey, geophysical and geochemical exploration were analyzed and the drilling exploration was carried out.
Although Pb mineralization was recognized in the survey area, the expected discovery of a high grade Pb ore deposit was not made in the project. A further survey is recommended.

9. Utilized Data: Geological maps.

Reference No. C-13

1. Name of Project: "Projeto Serra do Quattpurce"

2. Executing Organizations: CVRD/DOCEGEO

3. Duration: 1972 - 1976

4. Objective: To explore nonferrous metal ore deposits.

5. Covered Area: Refer to the index map (Plate III-3)(22,500 ha.).

6. Methods: Geological survey and geochemical exploration.

7. Given Data: One report, two geological maps (1:1,000,000 and 1:50,000), one location map of geochemical exploration sites (1:250,000).

8. Results of Geochemical Survey:
Details of the project remain unknown, for the project report is not available in a complete form with maps and other references.

9. Utilized Data: One location map of geochemical exploration sites.