increment) is 12 to 30 est/ha. The log price is Cr$7,000/est (with bark) or Cr$9,000/est. (without bark).

9-1-4 Current Situation of Reforestation

The current situation of natural forest management and artificial plantation will be described in this section. Fd_2 and Fd_3 of the tropical humid forest zone, and Fd_2 of the tropical sub-humid forest zone are the forest types in which natural forest management — considered to be the main system for future reforestation — is carried out.

Natural forest management is basically a management system to sustain natural forest, while at the same time producing wood from natural forests. This system prevents the productive power of the forest from declining both in terms of quality and quantity. Article 15 of the Forest Code prohibits careless development of the virgin forests in the Amazon basin and stipulates that forest exploitation in this area is only permitted when carried out under a program which incorporates management, maintenance and technological policies which comply with government regulations. However, the present state of logging and the logged over areas in objective areas where the natural forest management has been carried out, suggests that the principle and the spirit of the Forest Code have not always been practiced.

From site interviews it is obvious that the tree species in the natural forest to be logged are determined by users, that are, saw mills, plywood mills and wood working factories, forcing the loggers to concentrate their felling on certain valuable species. It is also clear that felling has been concentrated in the Varzea forest (a forest on the seasonal flooded area) with its convenient waterways and proximity to point of sale. Further, without utilization of lesser known the species, only valuable timber continues to be cut, bringing about the degrading of the forest resources in the area. As a result of forest development, in the past few years logging areas along the waterways have shifted to the plateau forest (dry land high forest) and the inner reaches of the Varzea forest upstream of the Amazon. Concomitantly, in the case of land transportation, the distance from the logging areas to the trunk roads has increased.

This form of timber production, named "gathering forestry", seems to be unsophisticated. Normally, when natural forests are cut and natural regeneration is used as the recovery method, consideration must be given to the regeneration of the logged over areas at the time of selecting trees to be cut, and a management system that does not cause degrading of forests must be adopted. Therefore, if degrading is inevitable because of the stand composition, it is necessary to actively carry out supplemental planting of commercial tree species in order to maintain the harvested areas as commercial forests. An on-site survey has revealed that though the forestry experts have this idea in mind, they have not yet put it into practice. Brazil, having the world's largest tropical humid forest, will investigate natural forest management of tropical humid forests so that industrial application can develop. This can only come about through practical experiments.

Regarding to the current situation about the establishment of man-made forests in Brazil as a whole, the southern states are the most advanced both in terms of the extent of man-made forests and technology. In contrast, artificial reforestation in the PGC Area are obviously underdeveloped. In the southern states most of the planted trees are of species introduced from abroad (e.g., Eucalyptus spp., Pinus spp., etc.), and there are only a small number of native species (e.g., Araucaria angustifolia). Logs from these exotic species are used mostly for industrial materials such as pulp wood, and some Eucalyptus is used as fuel wood. As a result, sawtimber for building and furniture has to be imported from either the northern states or abroad.

From this viewpoint it is important to establish an artificial reforestation system incorporating the natural forest management system mentioned previously, in order to prevent the PGC Area having vast forest resources, from being depleted as was the case in the southern states.

In the PGC Area the following areas have been chosen for artificial reforestation.

(1) Tropical humid forest zone

Fd_1 in this zone, with plentiful rainfall, could be suitable for artificial plantation or enrichment planting in natural forests. At present, however, there are few large-scale industrial plantations. With artificial reforestation still in the experimental stage only wood processing factories are undertaking the obligatory artificial planting in accordance with the provisions of Article 20 of the Forest Code. The main planted tree species are Pinus caribaea and other fast growing species; native species for plywood such as Ucuuba (Virola spp.) Sucupira (Diplotropis purpurea) are being planted on an experimental basis.

(2) Tropical sub-humid forest zone

Fd_1, Fa_1 and Fa_2 in this zone are suitable for artificial reforestation designed to actively improve the stands and convert the species. Presently, however, except for the obligatory plantation required under the Code, there is no planting in large scale.

(3) Semi-humid - semi-arid forest zone

This forest zone consists of S (Savanna forest) and Fde (Deciduous forest). The whole zone, including other forest types distributed in small areas, is suitable for artificial reforestation. Actually, however, there only a few scattered areas planted with Eucalyptus spp.

In summary, in the tropical humid forest zone, emphasis is being placed on natural forest management; the tropical sub-humid zone can be considered suitable for natural forest management and artificial reforestation in the future; the semi-humid - semi-arid zone can become a future artificial plantation area. In areas around Bacabal, Imperatriz and Maraba, which are the centers of development, there are already some moves, although not strong, to plant artificially (mainly Eucalytus). To consolidate this trend, however, factories need to be constructed in or near the zone to consume the timber and charcoal produced there (Provisions of the Brazil Forest Code concerning reforestation (Articles 17 - 21) are shown in Appendix).

9-2 Comments on Forestry Development Strategies

9-2-1 Site Classification in Forestry Development

Forestry development depends, to a large extent, on the natural and economic site of the forests. That is to say, compared with agriculture and manufacturing, in the case of forestry development, there is relatively little scope to improve the natural and economic conditions of the area where the development is planned. In general, forestry development is hardly to be carried out, especially in the early stages of development, if the conditions of the existing natural environments, natural resources and socio-economic infrastructures are poor. Considering this characteristic of forestry, strategies for forestry development in the PGC Area have been examined in terms of site classification (to be detailed later).

The natural condition crucial for forestry development is climate; it determines the type of forest and soil, as well as vegetation. It was therefore decided to divide the PGC Area into the following climatic zones (forest type zones) to facilitate the study of development strategies (These zones are shown in Figure 9-2).

Tropical humid forest zone	(H) area
Tropical sub-humid forest zone	(S) area
Tropical semi-humid - semi-arid forest zone	(A) area

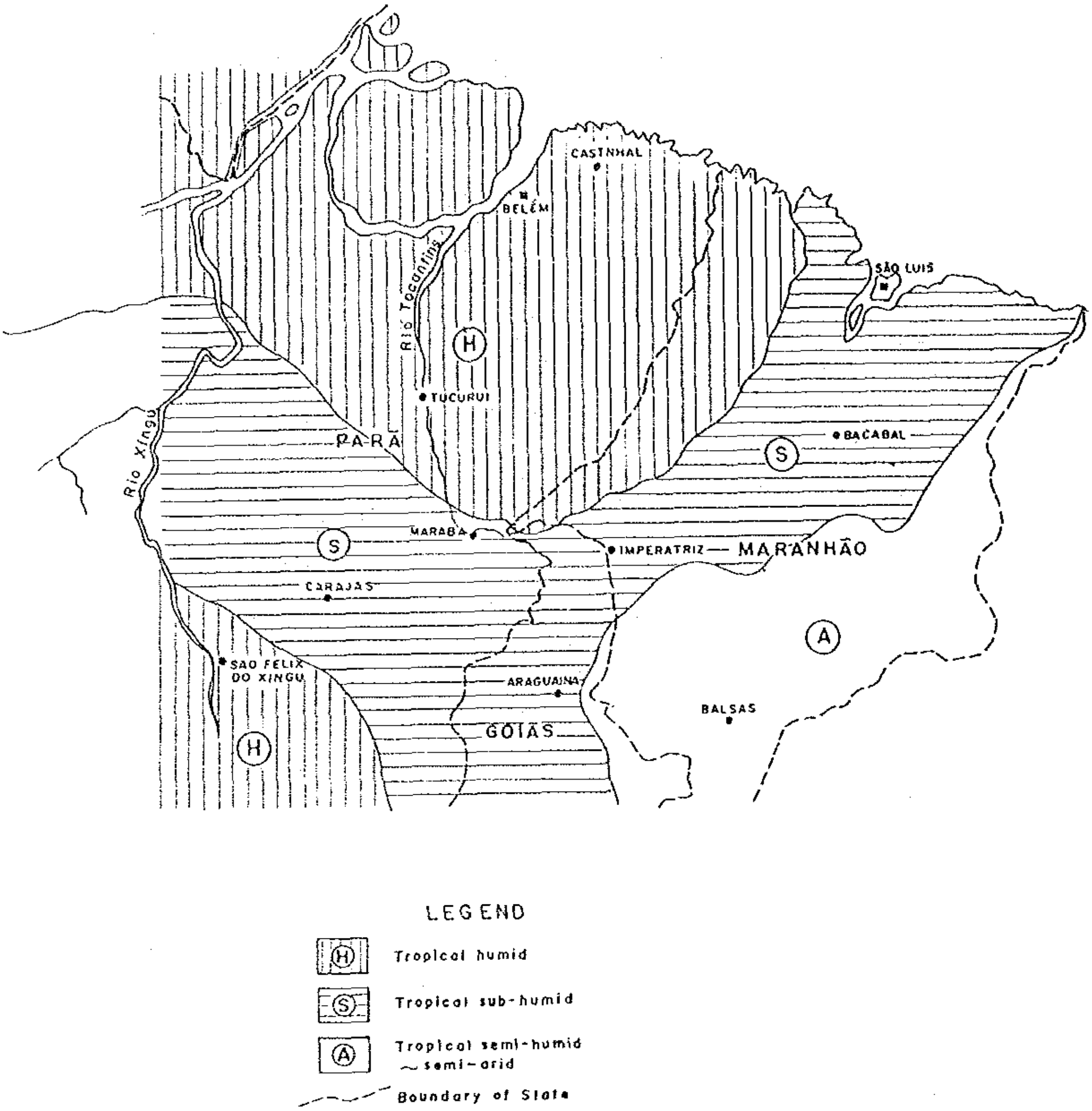
Division by sub-region in the PGC Area is as follows:

(H) : Castanhal (Belem), Tucurui, downstream Maraba and most of the Xingu river basin
(S) : Upstream Maraba, Imperatriz, Bacabal and part of the Xingu river basin
(A) : Araguaina, Balsas

The coastal/tidal forest zone mentioned in the previous Section is not in the climatic climax stage but rather in the edaphic vegetation stage, and thus is not marked for forestry development untouched for reasons of preserving the natural environment. For this reason it was excluded from the present study.

Transportation -- by road, waterway, and railway -- is the major economic factor in forestry development. Transport conditions between the gathering areas of the forest's raw materials (logs) and the proc-

Figure 9-2 Climatic Site Class



essing and consuming areas (markets) critically effect the ease or difficulty of forestry development. Especially, transportation between the log gathering areas and the processing areas is the most influential factor that determines the feasibility of logging operations.

Accordingly, when the viability of transportation is to be determined by the distance from logging area to the nearest road or waterway, it is difficult to decide exactly the distance on which logs can be collected. Nevertheless, using the ongoing farmland development as a guide, it was decided that the areas within 100 km of either side of a main road are favorable (indicated by "ⓐ"), and areas outside that range are unfavorable (indicated by "ⓑ").

By combining the above three natural conditions and two economic conditions, the following six site class divisions can now be delineated:

Ⓗ - ⓐ : Tropical humid and economic site class is favorable.
Ⓗ - ⓑ : Tropical humid and economic site class is unfavorable.
Ⓢ - ⓐ : Tropical sub-humid and economic site class is favorable.
Ⓢ - ⓑ : Tropical sub-humid and economic site class is unfavorable.
Ⓐ - ⓐ : Semi-humid/semi-arid and economic site class is favorable.
Ⓐ - ⓑ : Semi-humid/semi-arid and economic site class is unfavorable.

All discussion on forestry development strategies to be outlined below, especially for forest exploitation, reforestation and introduction of agroforestry, all of which are greatly influenced by the site conditions, is made according to the these site classifications.

9-2-2 Forestry Development

As mentioned in the preceding Section, the term "forest exploitation" has two meanings: (1) "forestry use" whereby the timber resources are obtained through selective or clear cutting, and logged-over-areas are restored to forest through natural regeneration or artificial reforestation, and (2) "conversion of forests" whereby farms and pastures are developed after the forests are cut. In this Section forest exploitation in the PGC Area is studied from both these aspects.

In general, forestry use, unlike the case of conversion to arable land, areas where the economic site conditions are less advantageous are often selected. Forestry use is also active in the area where the quality of the existing forestry resources is good. This is attributable to the lower land productivity in the case of forestry use, compared with the case of agricultural use, and the forest industry being heavily dependent on existing resources.

Based on the above considerations, the following concept for site classification has been derived, and suggestions are made as to where emphasis should be placed -- agriculture or forestry -- in the area where forest exploitation is carried out under the Greater Carajas Program.

- Areas where forestry use is dominant:

Ⓗ - ⓐ, Ⓗ - ⓑ, Ⓢ - ⓑ

- Areas where agricultural use is increasing:

Ⓢ - ⓐ, Ⓐ - ⓐ, Ⓐ - ⓑ

In developing these areas, a certain extent of forests in specific locations must be preserved to maintain the natural environment, irrespective of forestry or agricultural use.

From these points of view, forest exploitation will be described below along with land use classification and forest type.

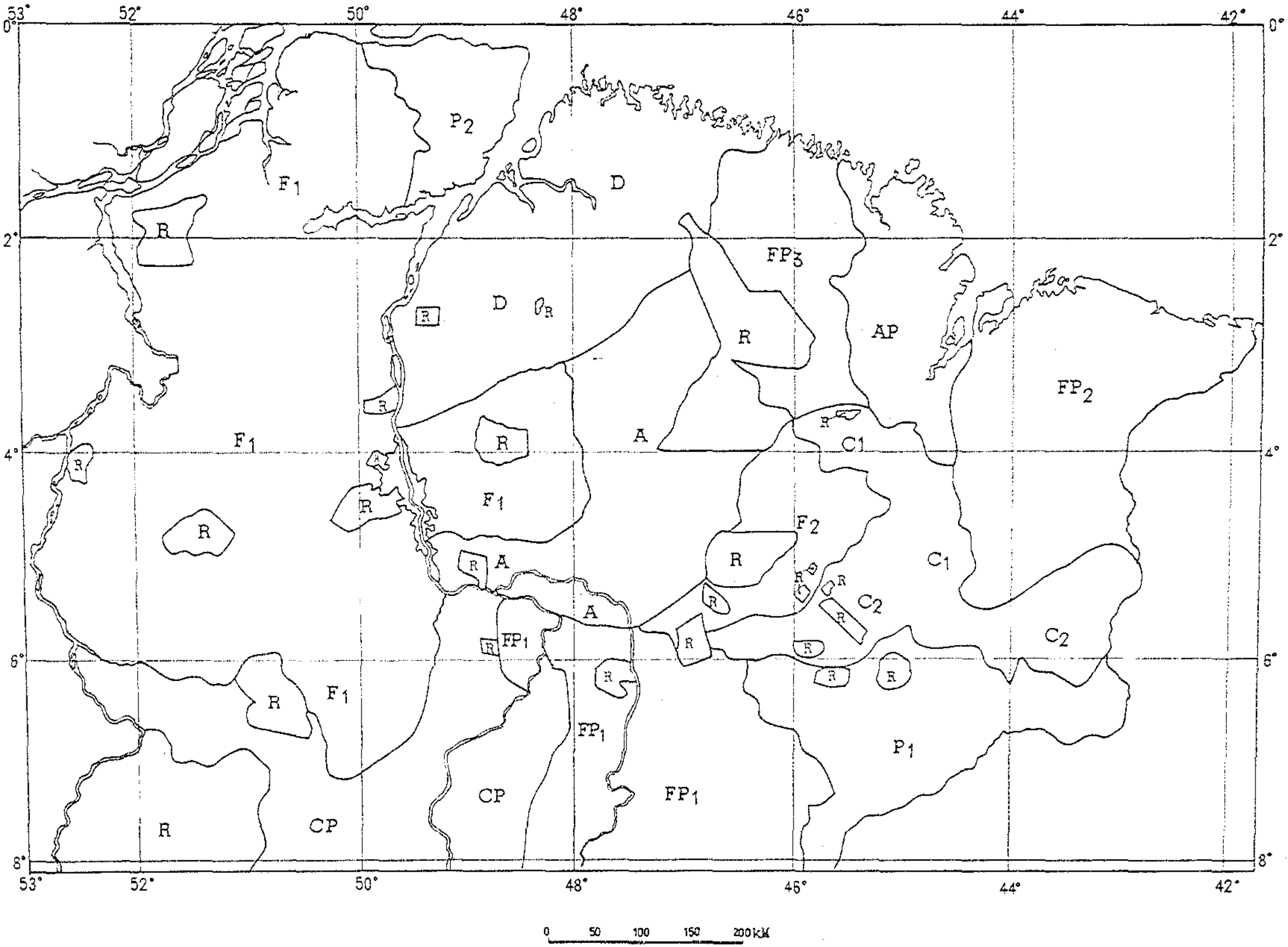
According to the agricultural potential map made by the Ministerial Council, the dominant areas for forestry use are located mostly in F_1 and F_2 (see Figure 9-3). The greater part of the F_1 district lies between the Tocantins and Xingu rivers, with part of it extending to the east of the Tucurui Dam, across route PA-140 and approaching the national route BR-010 (Belem-Brasilia highway) The F_2 district is located 100 km to the east of national route BR-010, and 70 km west of Bacabal, between four to six degrees south latitude. The area is relatively small, being less than one-tenth that of F_1.

Area F_1 represents the most suitable location for forestry use in terms of climate and economic site class. The following areas are now suitable for timber production using a combination of water and land transport: the two Ⓗ-ⓐ ranked areas, which lie to the north and south of the eastward flowing tributary of the Anapu river and its lower tributary; the Ⓢ-ⓐ division, including the Carajas Mountains; and Ⓢ-ⓐ, which lies to the east of the Tucurui Dam (see Figure 9-2). It is unavoidable that present felling in these areas is concentrated on commercial species. In regenerating the forest stand, however, measures such as natural regeneration support works or enrichment planting, need to be considered to prevent degradation of the forests resources.

The area east of the Tucurui Dam, in particular, is expected to develop and deforest rapidly due to (1) its convenience for timber extraction, and (2) its proximity to such timber processing centers as Acailandia and Imperatriz.

To ensure sustained and stable development of forestry in the future, promoting of natural regeneration or artificial enrichment with the commercial native species should be carried out after felling to prevent forest degradation. In this area, apart which has underdeveloped waters and land routes, making timber extraction extremely difficult. Although BR-230 (Trans-Amazon highway) runs through the area, it is not in a condition in which large amount volumes of timber can be transported. It is desirable that this situation will be improved.

Figure 9-3 Potential



LEGEND for Figure 9-3

1. PROGRAMA ÁLCOOL *ALCOHOL PROGRAM*	A	Cana-de-açúcar + sorgo, mandioca, pastagem, seringueira, grãos, pimenta-do-reino *Sugar cane + sorghum, cassava, pastures, rubber, grains, pepper*
2. EXPLORAÇÃO FLORESTAL *FORESTRY*	F_1	Exploração florestal sustentada + castanha *Forestry (sustained yeld) + Brazil nut*
	F_2	Exploração florestal (manejo sustentado + reflorestamento) + pastagem *Forestry (sustained yeld + reforestation) + pastures*
3. MADEIRA/PECUÁRIA *LUMBER/CATTLE*	FP_1	Reflorestamento e pastagem + culturas em geral *Reforestation and pastures + crops*
	FP_2	Reflorestamento e pastagem + caju, coco, babaçu *Reforestation and pastures + cashew, coconut, babassu*
	FP_3	Pastagem e exploração florestal + culturas em geral *Pastures and forestry + crops*
4. PROGRAMA DENDÊ *OIL PALM PROGRAM*	D	Dendê + seringueira, cacau, pimenta-do-reino, guaraná, castanha, arroz, milho, feijão, mandioca *Oil palm + rubber, cacao, pepper, guarana, Brazil nut, rice, corn, beans, cassava*
5. CULTURAS *CROPS*	C_1	Arroz, milho, feijão, soja + algodão, mandioca, babaçu, cacau, cana-de-açúcar *Rice, corn, beans, soybeans, cotton, cassava, babassu, cacao, sugar cane*
	C_2	Arroz, milho, feijão, soja + algodão, mandioca, babaçu *Rice, corn, beans, soybeans + cotton, cassava, babassu*
6. CULTURAS/PECUÁRIA *CROPS/CATTLE*	CP	Milho, soja, pastagem + arroz, feijão *corn, soybeans, pasture + rice, beans*
7. ARROZ/PECUÁRIA *RICE/CATTLE RAISING*	AP	Arroz e pastagem + babaçu *Rice and pastures + babassu*
8. PECUÁRIA *CATTLE RAISING*	P_1	Pastagem + caju *Pastures + cashew*
	P_2	Pastagem + arroz *Pastures + rice*
RESERVAS *RESERVATIONS*	R	Reservas Indígenas e Florestais *Indian and forestry reservations*

The area on the east side of the Xingu river, which has been designated a Fa forest type, has little prospect for the time being as a *commercial timber production area*. Since it is considered geographically difficult to improve the forest type by active tending, it will be able to convert from Fa to Fd dependent on natural recovery and excluding human interference and to develop a tropical forest resource in the twenty-first century.

Though small in area, the Fa forest type has the Carajas Railway and routes BR-222 and MA-006 running through it, and is conveniently located near such processing places as route BR-010 (Belem-Brasilia highway), Acailandia, Imperatriz, and Sao Luis; this area is thus designated as Ⓢ-ⓐ. The forests in this area occupies a geographically favorable position and has the potential of being converted into a land use other than forestry. If forestry development is to be undertaken, the forests should be either under the control of the federal or state government or regulated by law. This area is situated between two babassu forests, of which the centers are Bacabal and Imperatriz, and it has the potential of being easily converted into an area of dominant babassu forests, by removing the upper canopies. Careful consideration should therefore be given to the selective logging of the natural forests in this area through sufficient tending and enrichment planting. Depending on the condition of the forest bed, artificial reforestation with commercial native species needs to be developed.

According to the map made by the Council, there are forests that have been targeted for uses other than forestry use (see Figure 9-1). Firstly, the area designated as D produces mainly oil palm, as well as cacao, pepper, and rubber. This area, comprising tropical humid forests and forest types Fd_3 and Fd_2, is the most productive and valuable forest in the PGC Area. At the same time, it is situated in a geographically advantageous position, making it ideal for conversion to more productive land use. In that case, it is apparent that an enormous amount of log could be produced in a short period and the amount of log production may far exceed demand. The same can be said of area A, which is adjacent to area D and extending on both sides of route BR-010. In this area, the cultivation of alcohol-producing sugarcane, sorghum, and cassava will be worth consideration.

The short-term log production brought about by such conversions is closely related to log production in site classes Ⓗ-ⓐ and Ⓢ-ⓐ. As a result, when considering the development of the whole PGC Area, careful coordination, for example, promotion of marketing and/or staggering of the felling in each area, is necessary. Every effort must be made to avoid burning up, and it is hoped that policies will be implemented to make possible timber utilization particularly for lesser known tree species.

The area designated Fp is being considered for development through a combination of forestry and livestock farming. There are two combination methods: vertical and horizontal. The former involves a management system called silvo-pastoral, but as this system is still in its infancy, it is considered too early to adopt it in large scale for the development of this Area. In the latter, the land is divided into the blocks to be used for forestry and livestock farming. In the blocks for forestry use, the suitable forest management system will be applied. Discussion will be made for the latter.

The forest types Fp_1 and Fp_2 are located in the semi-humid - semi-arid forest Zone: Ⓐ so natural forest management system hardly to succeed as a silvicultural system. When the forests are exploited for firewood and charcoal production, the trees now growing will be clear cut. Then, the cut over areas will be planted with improved tree species and the planted areas will be positively managed as a man-made forest. As for the deciduous forests indicated by Fde in the map of forest types, and cerrado and cerradao in the savanna forest, the tree species to be planted should be selected according to the climatic and soil conditions. Both Fp_1 and Fp_2 are situated in a geographically favorable region (Ⓐ-ⓐ), and this convenience can be expected to increase as the construction of roads proceeds with the development of livestock farming. This Ⓐ-ⓐ region has many areas where forests have already disappeared; and for the remaining natural forests, from the viewpoint of the common property (e.g., environmental protection), protective measures should be taken where necessary, and attempts made to improve forest stand by artificial reforestation. In this area deforestation should be strictly forbidden within 50% of forest area stipulated by the Forest Code to be preserved. It is desirable that the allocation of these forest reserves be planned by official specialists on the basis of site conditions and giving regard to the soil conservation, water reservation and protection of natural environments.

Careful consideration must be given to areas of serious soil erosion such as the savanna forest. If necessary, one method may be setting up forest belts along the contour lines at certain intervals to prevent soil erosion, or leaving untouched the existing natural forest belts along the sides of rivers.

Zone Fp_3 has the Gurupi river running through its center, and it contains natural forest that belongs to the tropical humid forest zone: Ⓗ designated as forest type Fd_2. This natural forest, which as a whole, has an abundant growing stock and a number of commercial species, is convenient for extraction; it therefore can be exploited rapidly. However, at the forestry development and livestock farming in the basins of the Maracacume river and other rivers, the provisions of Articles 2 and 3 of the Forest Code should be strictly observed. Natural forest management and artificial reforestation will be carried out in this areas. When artificial reforestation is carried out, commercial native species should be used for planting. However, if pulp mills or iron-works using charcoal are to be constructed in the Castanhal or Sao Luis in the near future, planting a fast growing species is considered advantageous in terms of internal return.

The overall distribution of Fd_3 (closed forest type) shows that some of the areas which should be ranked potentially as Fd_3 are classified as Fd_2 or Fd_1. Most of these areas are located along rivers that lie in the tropical humid forest zone. A case in point is forest type Fd_3 that lies isolated to the north of the Anapu river. It can be said that, though this forest type was once connected to Fd_3 which lies on the southern side of the river, the close proximity of waterways facilitated the forest exploitation on both sides, thereby making this forest type revert to type Fd_1.

It is hoped that forests along rivers will be managed as water conservation forest and basin protection forests, and future forestry development will be carried out in accordance with the systems provided for under the Forest Code. To summarize, further measure should be introduced to secure proper forest development in compliance with laws and regulations should be reinforced; for example, a concrete system such as designating which forests to be reserved should be examined so that the designated forests can be fully protected by the restriction of forest exploitation.

9-2-3 Development of Forest Industry

To describe the development of the forest industry in the PGC Area, industry is divided into a) logging operations, b) the timber processing industry, and c) the wood material industry.

The logging industry in the PGC Area is, as mentioned earlier, still in a relatively unsophisticated stage. Generally, the modernization and rationalization of logging operations is mutually concerning to the improvement of forest management, development of the timber wood industry upgrading of related fields such as social and economic development of the region.

For example, logging business in Southeast Asia and tropical Oceania have advanced simultaneously with social development: public facilities such as roads, ports, village amenities have been constructed, and wood processing industries and resettlement and reforestation projects established. It then became possible to extract soft and light wood, which had previously not been utilized on the assumption that they were non-commercial, by exporting them in the form of logs. As a result, the logging business improved both in terms of management and production amount.

With this example in mind, to develop the logging industry in the PGC Area, which has similar conditions as those in Southeast Asia, especially in the Amazonia region (Ⓗ-ⓐ and Ⓗ-ⓑ zones), the measures considered most effective are federal or state aid programs, policies aimed specifically at building the infrastructure (such as roads), encouragement of the utilization of lesser known tree species, and expansion of log exports.

The main problems facing the development of the wood processing industry, mainly sawmills and plywood mills, in the PGC Area are a) even though the logs have good quality, so many species of logs are obliged to be used as raw material, and b) the local demand for timber products is low even though the demand is high in other parts of Brazil and abroad.

To overcome these problems the level of processing and marketing should be raised to increase the value added of the products and to utilize the inherent value of the tree species. The following suggestions can be made.

(1) Measures to improve the sawmill industry

- Replacement of obsolete facilities:
  By improving the physical location of each piece of equipment, converting a manual to the automatic one, improvement of work efficiency, checking crooked sawing, irregular widths and surface defects.

- Improvement in the recovery rate of sawing:
  By training in the techniques and communalization of the residues utilization mill (e.g., common briquet mill), it is hoped that a recovery rate higher than 50% can be achieved.

- Acquiring international standards of quality:
  In order to raise the popularity of Brazilian wood products in the international market, emphasis should be placed on the introduction of artificial drying equipment and government training and aid to improve the product grade and standard.

- Expansion of marketing activities:
  It is desired that a central lumber yard will be set up in the producing area to facilitate the sales of sawnwood. It is appropriate that the government is intending to expand timber supply stations (entrepostos madeireiros) in the area that is producing products for export.

(2) Measures to improve the plywood industry

- Stable procurement of logs:
  The greatest problem facing plywood mills in the PGC Area is the difficulty of collecting in large quantities, logs as light, soft and as homogeneous as those in other countries. Therefore, it is desirable that the federal and state governments provide instruction and support in procuring these kind of logs.

- Enlargement of value added component:
  Since plywood is a product which usually faces keen international competition, it is desirable that the federal and state governments provide technical and financial support for the production of fancy plywood, lumber core, and furniture made of plywood, of which materials are abundant and which have a higher value added.

Finally, wooden material industries such as pulp and wood alcohol, are worth reviewing because of their importance in the PGC Area in the future. The raw materials for these industries should be homogeneous wood, that is, timber from man-made forests. Therefore, prior to the establishment of these industries in the Area, promotion of artificial reforestation with fast growing species is essential to ensure the procurement of these raw materials. For this purpose, an area having a sub-humid climate with conveniently located land transport routes, for example, the site class Ⓢ-ⓐ in the state of Maranhao, is considered suitable (The charcoal and reconstituted fuel wood industries will be discussed in Section 9-2-6).

9-2-4 Reforestation

Reforestation in the PGC Area can be divided into two types: one as a component of natural forest management, and the other, artificial reforestation. Much of the natural forest management carried out in the world's tropical humid forests by means of the shelter wood system, in which regeneration is mainly carried out naturally. The procedures of enrichment planting, soil treatment, girdling and improvement cutting are implemented under intensive natural forest management. Preliminary and after felling as part of harvesting are rarely done (The natural forest management in the PGC Area based on this working system will be discussed later).

Various methods can be adopted for artificial reforestation. The most common are clear cutting and planting, with line planting, planting by means of agroforestry, or a combination of planting and coppice regeneration also being used. For artificial reforestation in the PGC Area, adoption of these methods should be made according to the site conditions (to be described later).

Concerning these two methods of reforestation, there is the belief that artificial plantation, because it creates a homogeneous forest, is not desirable in consideration of the conservation of the natural environment. Since natural forests in the sub-frigid and the cool temperature zones in high altitudes tend to become homogeneous even if they are left untouched, conversion to heterogeneous forests is being attempted for the sake of forest conservation and soil improvement. However, in tropical climates, especially in the humid zone, forests naturally become heterogeneous. In terms of the relationship with people, due to the heterogeneous forest conditions, waste of forest resources is apt to occur. At the 5th International Forestry Congress, one of problems that the difficulties arising in forestry development in the tropical zone are lack of market and incomplete utilization due to heterogeneity of the forests, is still unsolved.

For this reason, it will be considered that converting the degraded and fragile natural forests to man-made forests in the PGC Area can be significant. Problems will arise if the idea of natural forests is adhered to too strongly, leaving the degraded natural forests as they are and ignoring the disappearance of forests. If conversion of natural forests to uniform man-made forests in large scale should be achieved by locating man-made forests between natural forests, leaving natural tree belts and mixing natural trees, the intentions of the conservation of nature and of genetic and wildlife conservation can be achieved.

Reforestation requires technical and financial support by the Government. In some countries, governmental or semi-governmental organizations are placed in specific areas as the implementation bodies providing such support. For example, the State Forestry Corporation (PERHUTANI) in Java, the State Forestry Enterprise (INHUTANI) in Kalimantan and Irian Jaya are carrying out logging and reforestation as the national or public organization. In the Sabah State of Malaysia, the Sabah Forest Development Authority (SAFODA), established as a public organization, is conducting artificial reforestation. In Japan also, the Forest Development Authority, set up as a special corporation, is conducting artificial reforestation in water conservation forests located in non-national forests.

Considering the importance of forests and forestry, and the potential for future foresty development in the PGC Area, the establishment of government-supported implementation bodies (such as the ones described above) for the purpose of reforestation is worth consideration.

The reforestation techniques suitable for each site class in the PGC Area can now be outlined.

(1) Site class Ⓗ-ⓐ: Tropical humid and favorable economic site class

To sustain the excellent tropical forest resources, the ideal form of reforestation for the natural forests in this site class is considered to be the shelter wood system, that is, selective cutting and natural regeneration including timber stand improvement. In the selective logging operation being undertaken in Amazonia, cutting is currently limited to about 20% of the total volume and around 40 m^3/ha. However, if the tree species formerly considered to be non-commercial are utilized, overall limitations could be removed; and leave off the cutting limit of non-commercial trees, the harvesting of non-commercial trees should be encouraged to improve the proportion of tree species in the forest in the future. In some Southeast Asian countries, for example, the cutting of non-commercial tree species in tropical rain forests is being encouraged in spite of costly operation.

In the degraded forests caused by logging operations and shifting cultivation, as well as in the second growth stage, it is recommended that artificial reforestation be carried out to convert them to forests of good quality. For artificial reforestation, a system of line planting, such as the Recru and Anderson methods being implemented tentatively by IBDF and Tropical-humid Agriculture Research Center (CPATU) should be adopted. The species to be planted should be those highly regarded as commercial timber, for example, Freijo, Andiroba, Tatajuba, and Mogno. Fast growing species should not be used until their marketability is determined.

(2) Site class Ⓗ-ⓑ : Tropical humid and unfavorable economic site class

Reforestation in this site class, whether it is by natural forest management or by artificial reforestation, is economically difficult, because of its unfavorable economic site. Accordingly, simply attempting to conserve the natural forests is the best alternative for the immediate future. It is recommended, however, that selective *cutting and natural regeneration* be carried out under the administration of the IBDF and other public organizations, and this management system be reviewed both in terms of technique and management.

(3) Site class Ⓢ-ⓐ : Tropical sub-humid and favorable economic site class

This site class experienced the largest deforestation due to the conversion to farmland. From the viewpoint of forestry, this site class is suitable for, and in need of, artificial reforestation. Nevertheless, the degraded natural forests in this area are not functioning to preserve the natural environment. Considering the clause of the Forest Code that requires 50% preservation of natural forests, these degraded forests have been left as they are. For the degraded natural forests left in this condition, it will be suggested that the regulation of the 50% preservation of natural forests be reviewed and that attempts be made to improve the forest stand by artificial reforestation.

The appropriate reforestation system in this site class would be clear cutting and the artificial reforestation system with Eucalyptus spp., Pinus spp. and other fast growing species, or native hardwood species for plywood. At the same time, in the degraded natural forests described above, line planting with tolerant broadleaved trees whose quality is of high commercial value might be considered.

(4) Site class Ⓢ-ⓑ : Tropical sub-humid and unfavorable economic site class

Because of its unfavorable site class, the main task will be to sustain the natural forests through the natural forest management system. If excessive agricultural development or forest exploita tion is carried out, artificial reforestation will be required to rehabilitate the forests.

(5) Site class Ⓐ-ⓐ : Semi-humid - semi-arid and favorable economic site class

On the assumption that timber demand will rise in the future for industrial purposes (pulpwood, spirit wood, and charcoal wood), in this site class, introducing of clear cutting and artificial reforestation with Eucalytus spp. Acacia spp. and other xerophilous fast growing species will be expected. The poor natural forests should be converted into rich artificial forests, in the sense described in Item (3) above, to facilitate their function of natural environments.

(6) Site class Ⓐ-ⓑ : Semi-humid - semi-arid and unfavorable economic site class

It is recommended that in this site class, at least for time being, the area and the quality of the existing natural forests be conserved and that the introduction of artificial reforestation along with the construction of road networks be considered for the future.

9-2-5 Introduction of Agroforestry

There are as many definitions of agroforestry as there are organizations and researchers dealing with the subject. Dr. B. Lundgren, Director of the International Council for Research in Agroforestry (ICRAF), an international agroforestry research organization, defines agroforestry as follows:[1)]

> Agroforestry is a collective name for land use systems in which woody perennials are deliberately grown on the same piece of land as agricultural crops and/or animals, either in some form of spatial arrangement or in sequence. In agroforestry systems, the woody component interacts ecologically and economically with the crop and/or animal components. Such interactions will take many different forms, both positive and negative, and they need not remain stable over time.

This and other definitions agree that agroforestry is a form of land use requiring that trees and agricultural crops and/or livestock be grown in combination with each other. Views differ as to whether this combination takes place on the same stand or involves combined raising on different stands. Opinion is also divided as to whether agroforestry and social forestry are similar concepts or, in fact, even synonyms.

In the present Study, for practical purposes, we have taken the broadest interpretation of agroforestry. To study the adaptability of agroforestry to the PGC Area, the various agroforestry techniques carried out in other countries can be roughly divided into four groups: (1) shifting fallow farming system, (2) TAUNGYA system, (3) multi-layer agro/pasture forestry, and (4) block agroforestry (see Figure 9-3).

(1) Shifting fallow farming system

The cycle of this system can be expressed diagramatically as:

forest→ cultivated area/pasture→ forest

This is the most rational system in terms of technology and society.

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1) B. Lundgren, ICRAF's Programme of Work for 1982, Jan. 1982.

For example, the types, "shifting cultivation" "corridor system" and "simulation of natural succession", classified by Weaver,[1] belong to this group.

(2) TAUNGYA

This involves the short-term inter-cropping of agricultural crops in the early stages of tree plantation. Some examples are TUMPANG SARI[2] (Indonesia), Forest village[3] (Thailand), SHAMBA system[4] (Kenya), and KOBASAKU forestry[5] (Japan).

(3) Multi-layer agro/pasture forestry

This is the continuous (or long-term) combination of more than one layer of trees, and either agricultural crops or livestock. "Tree inter-cropping", classified by Weaver, and "planting of sawtimber species, fruit trees, firewoods, fodder trees, fertilizing trees and shade trees on farmland or pasture" classified by Combe[6] correspond to this group.

(4) Block agroforestry

Woody components and agricultural components do not mix on the same land, grow separately and form groups. Included in these groups are "self-sufficient farms", "scattered or row trees" and "forest blocks" classified by Weaver, or "fence shelter tree belt" classified by Combe. Some of these groups are small, and, the blocks managed in tree gardening (Indonesia), social forest (the Philippines) and small holders' farming (Kenya) are small and each self-contained in one farm allotment. In PANCHAYAT forest (Nepal), on the other hand, the combination extends over a wide area, and the blocks are managed in one village.

These four groups are illustrated on Figure 9-4.

Patterns of agroforestry differ depending on a) the type of combination of tree, agricultural crops and livestock, b) whether the stand

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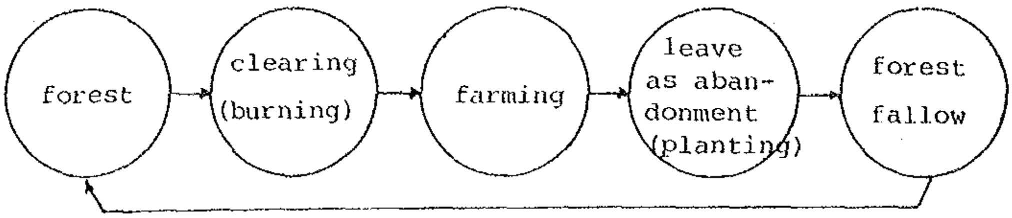
1) Peter Weaver, Agri-silviculture in Tropical America.
2) The TAUNGYA system with a combination of planted trees of teak, and maize, groundnut, etc. in the national forests of Java, Indonesia.
3) The TAUNGYA system with a combination of planted trees of teak, and terrestrial rice, beans, etc. by the Forest Industry Organization, Thailand.
4) The TAUNGYA system with a combination of planted trees of Pinus Cupressus and kale, carrots, potatoes, etc. in the national forests of Kenya
5) The TAUNGYA system with a combination of planted trees of cypress, cedar and beans, buckwheat, potatoes, etc. in the privately-owned forests of Japan.
6) Jean Combe, "Agroforestry Techniques in Tropical Countries", ICRAF Agroforestry Systems, International Journal Vol. 1, No. 1, 1982

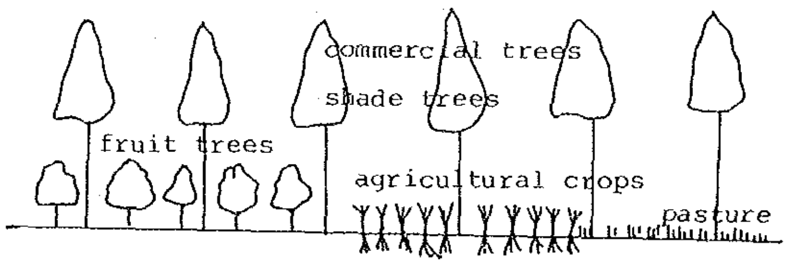
Figure 9-4 Agroforestry Groupings

1) Shifting fallow farming system

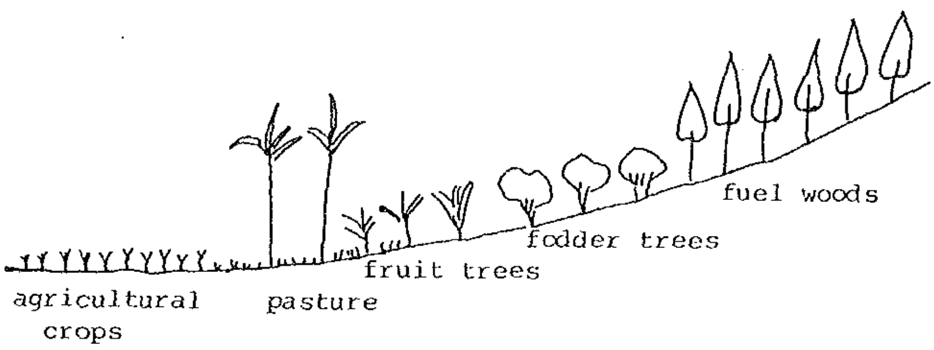


2) TAUNGYA system

3) Multi-layer agro/pasture-forest



4) Block agroforestry



is privately owned, communal or owned by other parties, c) whether the combination of forestry, agriculture and stock farming is on the same stand or not, and d) whether the main objective of the agroforestry is to promote agriculture, to encourage reforestation, or to benefit the local people.

In the case of TUMPAN SARI in Indonesia, a) the type of combination is a combination of trees (teak) and crops (rice, maize, beans, etc.); b) the ownership is inter-cropping by farmers on the stand owned by others (national forest), c) the spatial arrangement is raising on the same stand, and d) the objective is an establishment of mainly man-made forests. In the case of Indonesian tree gardening, the patterns of KEBUN and TALUN are, a) a combination of trees (artificial or natural) and crops, b) communal land, c) on the same stand or on small blocks, and d) the main aim is agricultural production.

Based on the above discussion on agroforestry, the introduction of agroforestry into the PGC Area is described below for each site class.

(1) Site class Ⓗ-ⓐ : Tropical humid and favorable economic site class

For this site class, a combination of fruit trees (cacao, Brazil nut, etc.) and trees of fast growing species that function as shade trees for the fruit trees is considered to be the most promising agroforestry system. Cacao, in particular, is a cash crop suited for tropical humid climates. As shade trees, fast growing species of the legume family, especially Albizzia (Paraserianthes) falcataria, can serve as fertilization trees; they form a favorable intensity of shade, grow fast (harvesting age: about 10 years) and have wide varieties of wood use. Therefore, the combination of Albizzia falcataria and cacao is suitable.

This system belongs to the multi-layer agro/pasture forestry group, because its combination extends over long periods. In terms of the management system, it may be appropriate for large land owners to carry out two operations, cocoa cultivation and timber production, in the form of plantations. There is already a cacao plantation near Belem in which Erythrina indica and Inga spp. are the main shade trees planted. However, since these species grow relatively slowly, we recommend the introduction of Albizzia.

This type of agroforestry is widely carried out in Southeast Asia. For example, in the State of Sabah, Malaysia, the Sabah Softwood Company is carrying out a combination of natural Dipterocarpus forest management and cacao plantation; while in the Philippines, social forestry is carried out using a combination of Albizzia and fruit trees. One form of agroforestry included under the TAUNGYA system, which is experimentally being undertaken in Amazonia region, is the inter-cropping of agricultural crops on the plantations with valuable hardwood. Some of these valuable hardwood trees are Cordia goeldiana (Frejo), C. alliodora (Frejo-louro), Swietenia macrophylla (Mogno) and Bagassa guianensis (Andiroba).

The recommended agricultural crops are rice, maize and legume, and the adoption of a fast growing species for the forest and perennial crops for agriculture is not desirable because they compete fiercely with each other.

Under the TAUNGYA system, the relationship among landowners, tree planters and inter-croppers is important. To implement the TAUNGYA system throughout this site class, the interests of the planters and inter-croppers must coincide and the type of land use must be appropriate. As the TAUNGYA system is still in the experimental stage, it must be made attractive to the people engaged in agriculture and forestry by studying it from the technical and management aspects in the future.

(2) Site class Ⓗ-ⓑ: Tropical humid and unfavorable economic site class

Looking at the conditions of this site class, it is difficult to introduce agroforestry for the time being. As for the primitive shifting cultivation occurring sporadically, while attempting to prevent environmental destruction by adopting a rational fallow system, instruction will be given on the "shifting fallow farming system". The aim of this system should be to provide the means by which settlers produce their own food, while also conserving the natural forests.

(3) Ⓢ-ⓐ: Tropical sub-humid and favorable economic site class

Agroforestry in this site class should basically be the same as that in site class Ⓗ-ⓐ. There is little difference in species and crops to be planted, though some degree of difference is to be expected. In the "multi-layer agro/pasture forestry" group for example, Grevillea robusta and Casuarina spp., as well as the fast growing species of the legume family, should be tested as shade trees. The plantation of coffee under shade trees is worth considering in the suitable natural conditions.

In terms of the TAUNGYA system as well, the situation of this site class is basically the same as that of site class Ⓗ-ⓐ, except that fast growing species such as Eucalyptus and such medium-cycle crops as cassava and banana can be introduced.

(4) Ⓢ-ⓑ: Tropical sub-humid and unfavorable economic site class

In this site class, the agroforestry products are hardly to transport and sale faster, smoother and easier than that in Ⓢ-ⓐ site class at present.

Land use with a combination of natural babassu and pasture, now found in wide areas across the state of Maranhao, is one pattern of agroforestry called "multi-layer agro/pasture forestry". In this site class, a combination of this babassu and pasture would be useful. However, the present combination is too extensive and there are many aspects of land productivity and soil conservation that need to be improved. Intensification of this kind of agroforestry should be considered.

(5) Ⓐ - ⓐ : Semi-humid - semi-arid and favorable economic site class

The type of agroforestry likely to be suitable for this site class is silvopastoral (mentioned previously). However, in this site class, which has the favorable economic conditions, the pasture should be high producing, similar to improved pastures. If the supply of fodder and improvement of soil are the aims, fast growing species of the legume family, for example, Erythrina spp., Cassia spp., Acacia spp. and Prosopis spp., etc., are suitable as the woody component. If, however, timber production and the creation of shaded areas are the objectives, fast growing species, such as Eucalyptus spp., Melia spp., Pinus spp. and Brachiaria, are recommendable.

What should be taken into consideration concerning this silvo-pastoral system is that, different from babassu, a grazing system with partitions should be adopted to protect planted trees from livestock in early stage of the plantation.

(6) Ⓐ - ⓑ : Semi-humid - semi-arid and unfavorable economic site class

In the present situation, agricultural and forestry production can not be expected to increase in this site class through the promotion of agroforestry. However, it is desirable that intensification of the silvo-pastoral combination of babassu mentioned in Item (4) above, and improving pasture should be tried where forests have already disappeared to make way for extensive pasture.

9-2-6 Introduction of Agro-industry by Forest Products

Among the forest products (products other than timber, called "forest by-products") that can be grown to improve the agro-industry, the production of charcoal, reconstituted charcoal (briquet), compressed reconstituted fuel wood, medicinal plants, Brazil nut (Castanha do Para), palm such as babassu, palmito, is considered feasible in the PGC Area.

(1) Charcoal

This is one of the substitute energy sources for oil to which Brazil has been attaching great importance. The potential of charcoal wood supply is very high in the area of tropical humid forests and the savanna in the PGC Area. However, as shown in Table 9-6, the actual production amount is considerably low compared to that of Brazil as a whole, the reason possibly being that demand for charcoal is low in the Area due to the absence of industries that use large quantities of charcoal.

It must also be recognized that in the southern states attempts are being made to reduce costs through rationalization of the production and transportation systems, and that demand and supply is virtually balanced in large charcoal consuming areas. The same situation applies in the case of reconstituted charcoal. Consequently, in order to encourage charcoal production in the PGC Area, measures should be devised to expand demand by initially encouraging the charcoal-consuming industries.

Table 9-6 Charcoal Production

(unit: tons)

Area	1975	1977	1978	1979
Within related 3 states	-	107	130	152
Brazil as a whole	4,032,000	4,165,000	4,714,000	

Note: Figures for related states are totals of three states: Para, Maranhao, and Goias.
Source: IBGE

(2) Compressed and reconstituted fuel wood

The United States, West Germany, and Japan are proceeding on research, development, and utilization of compressed and reconstituted fuel wood. The main products and their materials are shown in Table 9-7.

To produce these products, fuel wood manufacturing plants are necessary, which may have little direct relationship to the agro-industry. As a material supplying source, however, the agriculture and forestry in the village level can not be neglected. In particular, the amount of saw mill residue such as waste wood and sawdust produced in saw mills is now 70% of log volume. In addition, the market prices of these reconstituted fuel wood are about 60 to 70% of those of kerosene.

It is recognized in Brazil that sources of wood-base energy obtainable from charcoal and wood-molded fuel is very important to the country as an alternative energy source for oil and coal. Brazil is fortunately rich in wood-base energy resources, and the development of production techniques as well as utilization of the resources is urgently required.

In the rural areas of Japan, for example, wood-base energy is utilized in fields such as food and timber processing, general industries, public facilities as well as in households.

Table 9-7 Types of Reconstituted Fuel and their Materials

Name of Products	Raw materials	Producing country
Ogalite	Sawdust, bark	Japan
Woodex	Sawdust, wood residue, bark, paper sludge	USA
Pellet fuel	Sawdust, chaff, waste polyethylene film for farming	Japan
Papa cube	Sawdust, wood residue, bark	USA

The proportions of energy consumed by plywood factories in the timber processing area are shown in Table 9-8. It can be seen that wood-base energy represents a large proportion of the total energy consumed.

The prices of household fuels in Japan are shown in Table 9-9. In terms of price per calories, charcoal is the most expensive while wood-molded fuel (pellet) is the cheapest.

Recent studies in Japan have shown that the addition of charcoal powder and pyroligneous acid into farming land serves to activate microorganizms, inducing propagation and contigion of rhizobiaceae or mycorrhiza in the soil, and thereby being effective for the growth of plants. Based on these study results, experiments are now under way. The method derived through studies or experiments seems to be very useful in saving chemical fertilizer on the one hand and in increasing the yield of farm produce on the other hand in Brazil, where large-scale development of cerrado areas is planned. In particular, it is hoped that a study will be made on the possibility of introducing this method for developing the agriculture in the extensive cerrado zone existing in the southern part of the PGC Area.

(3) Medicinal plants, Brazil nut, palm, and palmito

The development of medicinal plants has significantly increased in recent years. The variety of plants in the Amazon region is considered to be the largest on earth and some of the species are still undetermined. Even though these are not being developed enough because of poor conditions in terms of production, transportation, processing, marketing, etc., by searching for new uses and establishing a distribution system, the area has a bright outlook for the future (development of the uses of palm, including babassu, is discussed in the Chapter 6).

Table 9-8 Proportion of Energy Consumed by Japanese Plywood Factories

(Unit: %)

	Oil	Electric Power	Wood-base
1975	47.4	9.4	43.2
1976	41.9	8.1	50.0
1977	38.6	8.2	53.2
1978	34.9	9.5	55.6
1979	29.5	9.0	61.5
1980	20.6	9.4	70.0
1981	14.3	8.6	77.1
1982	10.9	8.5	80.6

Source: Japan Plywood Industry Union

Table 9-9 Comparison of Household Fuel Prices in Japan

Fuel	Price/10,000 kcal (US$)	Price/Unit (US$)	Calorie/Unit (kcal)
City Gas	0.64	0.32/m^3	5,000/m^3
Propane	0.86	2.09/m^3	24,320/m^3
Electricity	1.24	0.11/kW	860/kW
Kerosene	0.41	0.37/l	8,900/l
Wood-molded Fuel	0.24 - 0.29	0.10-0.12/kg	4,200/kg
Coal	0.70	0.20	6,670/kg
Charcoal	1.52	1.07/kg	7,000/kg

The cutting of Brazil nut trees is prohibited partly because of its rarity. To increase production, it is desirable that the densely grown Brazil nut plantation will be established and that the trees will be cultivated. The nuts are presently merchandised as they are, and it seems desirable that the production of processed nuts be reassessed to raise the value added.

Palmito does not grow in the form of plantation in the southern states and once harvested, the life of the palm is ended. The palmito growing in these area is mostly derived from Acai, which is highly germinative, having the characteristic of repeated production. It grows densely in marsh areas, and being popular for salads, it is exported to the U.S.A. and Europe. It is therefore possible that the PGC Area could become an area producing palmito as a specialized agroindustry product.

Some of the medicinal trees and plants growing in tropical humid forests are shown in the following table.

Scientific Name	Brazilian Name	Pharmaceutical Application
Cassia ferruginea	Canjiquinha	Bark as raw material source of tannin
Erythroxylum coca	Fruta de tucano	Leaves as raw material source of cocaine for drinking
Malpighia glabra	Cereja do Para	Fruit as digestive
Ceiba pentandra	Samauma commum	Leaves, bark and fruit as folk medicine
Carica papaya	Mamoeiro	Fruit as food and as raw material for heart stimulants
Achras zapota	Sapotilha	Fruit as raw material for food additives
Solanum aculeatissimus		Containing solanum, as a medicine for external additives

APPENDIX: BRAZILIAN FORESTRY CODE

CÓDIGO FLORESTAL

Lei nº 4.771 - de 15 de setembro de 1965 - Institui o Novo Código Florestal

O Presidente da República

Faço saber que o Congresso Nacional decreta e eu sanciono a seguinte Lei:

Art. 1º - As florestas existentes no território nacional e as demais formas de vegetação, reconhecidas de utilidade às terras que revestem, são bens de interesse comum a todos os habitantes do País, exercendo-se os direitos de propriedade com as limitações que a legislação em geral e especialmente esta Lei estabelecem.

Parágrafo único - As ações ou omissões contrárias às disposições deste Código na utilização e exploração das florestas são consideradas uso nocivo da propriedade (art.302, XI, b, do Código de Processo Civil).

Art. 2º - Consideram-se de preservação permanente, pelo só efeito desta Lei, as florestas e demais formas de vegetação natural situadas:

a) ao longo dos rios ou de outro qualquer curso de água, em faixa marginal cuja largura mínima será:

   1 - de 5 (cinco) metros para os rios de menos de 10 (dez) metros de Largura;

   2 - igual à metade da largura dos cursos que meçam de 10 (dez) a 200 (duzentos) metros de distância entre as margens;

   3 - de 100 (cem) metros para todos os cursos cuja largura seja superior a 200 (dezentos) metros.

b) ao redor das lagoas, lagos ou reservatórios de água naturais ou artificiais;

c) nas nascentes, mesmo nos chamados "olhos-d'água", seja qual for a sua situação topográfica;

d) no topo de morros, montes, montanhas e serras;

e) nas encostas ou partes destas com declividade superior a 45°, equivalente a 100% na linha de maior declive;

f) nas restingas, como fixadoras de dunas ou estabilizadoras de mangues;

g) nas bordas dos tabuleiros ou chapadas;

h) em altitude superior a 1.800 (mil e oitocentos) metros, nos campos naturais ou artificiais, as florestas nativas e as vegetações campestres.

Art. 3º - (*) Consideram-se, ainda, de preservação permanente, quando assim declaradas por ato do Poder Público, as florestas e demais formas de vegetação natural destinadas:

a) a atenuar a erosão das terras;

b) a fixar as dunas;

c) a formar faixas de proteção ao longo de rodovias e ferrovias;

d) a auxilar a defesa do território nacional, a critério das autoridades militares;

e) a proteger sítios de excepcional beleza ou de valor científico ou histórico;

f) a asilar exemplares da fauna ou flora ameaçados de extinção;

g) a manter o ambiente necessário à vida das populações silvícolas;

h) a assegurar condições de bem-estar público.

Parágrafo 1º - A supressão total ou parcial de florestas de preservação permanente só será admitada com prévia autorização do Poder Executivo Federal, quando for necessária à execução de obras, planos, atividades ou projetos de utilidade pública ou interesse social.

(*) A Lei nº6.001 de 19/12/73, estabeleceu normas para o corte de madeira nas florestas indígenas, conforme o seguinte artigo:

"Art. 46 - "O corte de madeira nas florestas indígenas, consideradas em regime de preservação permanente, de acordo com a letra "g" e § 2º do Art. 3º, do Código Florestal, está condicionada à existência de programas ou projetos para o aproveitamento das terras respectivas na exploração agropecuária, na indústria ou no reflorestamento".

Parágrafo 2º - As florestas que integram o Patrimônio Indígena ficam sujeitas ao regime de preservação permanente (letra "g") pelo só efeito desta Lei.

Art. 4º - Consideram-se de interesse público:

a) a limitação e o controle do pastoreio em determinadas áreas, visando à adequada conservação e propagação de vegetação florestal;

b) as medidas com o fim de prevenir ou erradicar pragas e doenças que afetem a vegetação florestal;

c) a difusão e a adoção de métodos tecnológicos que visem a aumentar economicamente a vida útil da madeira e o seu maior aproveitamento em todas as fases de manipulação e transformação.

Art. 5º - O Poder Público criará:

a) Parques Nacionais, Estaduais e Municipais e Reservas Biológicas, com a finalidade de resguardar atributos excepcionais da natureza, conciliando a proteção integral da flora, da fauna e das belezas naturais, com a utilização para objetivos educacionais, recreativos e científicos;

b) Florestas Nacionais, Estaduais e Municipais, com fins econômicos, técnicos ou sociais, inclusive reservando áreas ainda não florestadas e destinadas a atingir àquele fim.

Parágrafo único - Fica proibida qualquer forma de exploração dos recursos naturais nos Parques Nacionais, Estaduais e Municipais.

Art. 6º - O proprietário da floresta não preservada, nos termos desta Lei, poderá gravá-la com perpetuidade, desde que verificada a existência de interesse público pela autoridade florestal, o vínculo constará de termo assinado perante a autoridade florestal e será averbado à margem da inscrição no Registro Público.

Art. 7º - Qualquer árvore poderá ser declarada imune de corte, mediante ato de Poder Público, por motivo de sua localização, raridade, beleza ou condição de porta-sementes.

Art. 8º - Na distribuição de lotes destinados à agricultura, em planos de colonização e de reforma agrária, não devem ser incluídas as áreas florestadas de preservação permanente de que trata esta Lei, nem as florestas necessárias ao abastecimento local ou nacional de madeiras e outros produtos florestais.

Art. 9º - As florestas de propriedade particular, enquanto indivisas com outras, sujeitas a regime especial, ficam subordinadas às disposições que vigorarem para estas.

Art. 10º - Não é permitida a derruba de florestas situadas em áreas de inclinação entre 25 a 45 graus, só sendo nelas tolerada a extração de toros quando em regime de utilização racional, que vise a rendimentos permanentes.

Art. 11º - O emprego de produtos florestais ou hulha como combustível obriga o uso de dispositivo que impeça difusão de fagulhas suscetíveis de procar incêndios nas florestas e demais formas de vegetação marginal.

Art. 12º - Nas florestas plantadas, não consideradas de preservação permanente, é livre a extração de lenha e demais produtos florestais ou a fabricação de carvão. Nas demais florestas, dependerá de norma estabelecida em ato de Poder Federal ou Estadual, em obediência e prescrições ditadas pela técnica e às pecualiridades locais.

Art. 13º - O comércio de plantas vivas, oriundas de florestas, dependerá de licença da autoridade competente.

Art. 14º - Além dos preceitos gerais a que está sujeita a utilização das florestas, o Poder Público Federal ou Estadual poderá:

a) prescrever outras normas que atendam às peculiaridades locais;

b) proibir ou limitar o corte das especies vegetais consideradas em via de extinção, delimitando as áreas compreendidas no ato, fazendo depender nessas áreas, de licença prévia, o corte de outras espécies;

c) ampliar o registro de pessoas físicas ou jurídicas que se dediquem à extração, indústria e comércio de produtos ou subprodutos florestais.

Art. 15º - Fica proibida a exploração sob forma empírica das florestas primitivas da bacia amazônica que só poderão ser utilizadas em observância e planos técnicos de condição e manejo a serem estabelecidos por ato do Poder Público, a ser baixado dentro do prazo de um ano.

Art. 16º - As florestas de domínio privado, não sujeitas ao regime de utilização limitada e ressalvadas as de preservação permanente, previstas nos artigos 2º e 3º desta Lei, são suscetíveis de exploração, obedecidas as seguintes restrições:

a) nas regiões Leste Meridional, Sul e Centro-Oeste, esta na parte Sul, as derrubadas de florestas nativas, primitivas ou regeneradas, só serão permitidas desde que seja, em qualquer caso, respeitado o limite mínimo de 20% da área de cada propriedade com cobertura arbórea localizada, a critério de autoridade competente;

b) nas regiões citadas na letra anterior, nas áreas já desbravadas e previamente delimitadas pela autoridade competente, ficam proibidas as derrubadas de florestas primitivas, quando feitas para ocupação de solo com cultura e pastagens, permitindo-se, neses casos, apenas a extração de árvores para produção de madeira. Nas áreas ainda incultas, sujeitas a formas de desbravamento, as derrubadas de florestas primitivas, nos trabalhos de instalação de novas propriedades agrícolas, só serão toleradas até o máximo de 50% da área da propriedade;

c) na região Sul, as áreas atualmente revestidas de formações florestais em que ocorre o pinheiro brasileiro Araucaria angustifolia (Bert) - O. Ktze, não poderão ser desflorestadas de forma a provocar a elimintação permanente das florestas, tolerando-se, somente, a exploração racional destas, observadas as prescrições ditadas pela técnica, com a garantia de permanência dos maciços em boas condições de desenvolvimento e produção;

d) nas regiões Nordeste e Leste Setentrional, inclusive nos Estados de Maranhão e Piauí, o corte de árvores e a exploração de florestas só serão permitidos em observância de normas técnicas a serem estabelecidas por alto do Poder Público, na forma do art. 15.

Parágrafo único - Nas propriedades rurais, compreendidas na alínea "a" deste artigo, com área entre vinte (20) a cinquenta (50) hectares, computar-se-ão, para efeito de fixação do limite, além da cobertura florestal de qualquer natureza, os maciços de porte arbóreo, sejam frutícolas, ornamentais ou industriais.

Art. 17º - Nos loteamentos de propriedades rurais, a área destinada a completar o limite percentual fixado na letra "a" do artigo antecedente, poderá ser agrupada numa só porção em condomínio entre os adquirintes.

Art. 18º - Nas terras de propriedade privada, onde seja necessário o florestamento ou o reflorestamento de preservação permanente, o Poder Público Federal poderá fazê-lo sem desapropriá-las se não o fizer o proprietário.

Parágrafo 1º - Se tais áreas estiverem sendo utilizadas com culturas, de seu valor deverá ser indenizado o proprietário.

Parágrafo 2º - As áreas assim utilizadas pelo Poder Público Federal ficam insetas de tributação.

Art. 19º - Visando a maior rendimento econômico, é permitido aos proprietários de florestas heterogêneas transformá-las em homogêneas, executando trabalho de derrubada, a um só tempo ou sucessivamente, de toda a vegetação a substituir, desde que assinem, antes do início dos trabalhos, perante a autoridade competente, termo de obrigação de resposição e tratos culturais.

Art. 20º - As empresas industriais que, por sua natureza, comsumirem grandes quantidades de matéria-prima floresta, serão obrigadas a manter, dentro de um raio em que a exploração e o transporte sejam julgados econômicos, um serviço organizado, que assegure o plantio de novas áreas, em terras próprias ou pertencentes a terceiros, cuja produção, sob exploração racional, seja equivalente ao consumido para o seu abastecimento.

Parágrafo único - O não cumprimento do dispoto neste artigo, além das penalidades previstas nesta Código, obriga os infratores ao pagamento de uma multa equivalente a 10% (dez por cento) do valor comercial da matéria-prima florestal nativa consumida além da produção da qual participe.

Art. 21º - As empresas siderúrgicas de transporte o outras, à base de carvão vegetal, lenha ou outra matéria-prima vegetal, são obrigadas a manter florestas próprias para exploração racional ou a formar, diretamente ou por intermédio de empreendimentos dos quais participem, florestas destinadas ao seu suprimento.

Parágrafo único - A autoridade competente fixará para cada empresa o prazo que lhe é facultado para atender ao disposto neste artigo, dentro dos limites de 5 a 10 anos.

10. COMMENTS ON PRELIMINARY SCREENING OF PRIORITY PRODUCTS AND NECESSARY CONDITIONS FOR DEVELOPMENT

As referred to in the Introduction, the study on agriculture, livestock and forestry development consists of seven items, each of which has its own specific subjects to be studied. However, these seven different study items have the following points of view in common:

(1) Preliminary assessment of priority products for the PGC Area on the basis of its natural, technical, and socio-economic conditions;

(2) Investigation of the necessary conditions for the development of the Area's agriculture, livestock, and forestry sectors with a focus on the expansion of the production of these products.

From the above view points, this chapter will present a brief summary of the preceding studies by item, and some comments on preliminary screening of priority products and necessary conditions for development.

10-1 The Special Features of the PGC Area's Agriculture, Livestock and Forestry Sectors

The special features of the PGC Area's agriculture, livestock and forestry sectors which were clarified from comparisons of the Area with Brazil as a whole, and between the sub-regions of the Area can be summarized as follows:

(1) The Area is endowed with abundant land resources, and in general many forests and much unused arable land exist.

(2) However, rapid large-scale conversion of forests to arable land (mainly pasture) is under way together with a wide-spread practice of shifting cultivation, showing signs of deterioriation of natural environment in some areas.

(3) The structure of agricultural production is characterized by the coexistence of large number of small-size farms producing mainly subsistence food crops and large-scale cattle farms. The percentage of pastureland in the total area of arable land is remarkably high. The percentages of tenants and occupants in the total number of farm units are also high compared to other regions. The cultivation of commercial crops such as oil palm and soybean by using modern techniques has emerged in some sub-regions, but in general the technical level and land productivity are low.

(4) The utilization of forest resource is still at a primitive stage. The artificial reforestation is very limited.

(5) The seven sub-regions can be roughly divided into three groups according to natural conditions, history of settlement, and distances from main roads: (a) Bacabal, Balsas and Imperatriz with

a relatively long history of development, large number of small- and medium- size farms, and high percentages of tenant farms; (b) Araguaina, Maraba and Xingu with land conversion for agriculture being under way, relatively high percentages of medium- and large- size farms, and large percentages of pasture area; and (c) Castanhal with a relatively long history of settlement, a large percentages of small- and medium- size farms, a high percentages of owner-farms, and farmers' willingness to be engaged in commercial crop production by using modern technology.

From the above observations, the following view points seem essential for the future development of the PGC Area's agriculture, livestock and forestry sectors:

(1) The need to enhance efficient use of land resource to actialize the Area's development potential;

(2) Promotion of policy measures for improving the incomes of the overwhelmingly large number of small farms, and for immobilizing shifting farmers;

(3) Strengthening the competitiveness of commercial crops suitable to the utilization of local conditions; and

(4) Harmonizing development and environmental conservation.

10-2 The Surrounding Conditions of the PGC Area's Agriculture, Livestock and Forestry Sectors

The present conditions of the major natural and socio-economic factors surrounding the agriculture, livestock and forestry sectors of the PGC Area can be summarized as follows:

(1) The Area is favored geographically by being covered with vast land, and the land price is relatively low.

(2) The PGC Area belongs to the tropical zone, but there are differences among the sub-regions in soil and rainfall. Although there are differences among the sub-regions in the possibility of agricultural land expansion, in general the Area has high potential of land development for agricultural use.

    The maximum rainfall is registered in the Castanhal Sub-region (annually 2,700 mm or more). In the PGC Area, generally the rainfall is high in the northwest and gradually decreases southeastward, with the minimum being registered to the south-southwest of Bacabal (annually 1,100 mm or less). Sub-regions Xingu, Maraba, and Imperatriz, and part of sub-region Bacabal have soil of relatively high fertility. (The prevailing soil types are PV.LV at Maraba, LV. AQ at Imperatriz, LV.PV.AQ at Araguaina, LA at Castanhal, TR.PV at Xingu, PV.HL at Bacabal, and LV.AQ at Balsas.)[1]

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1) See Chapter Two for details of soil classification.

Generally, considerations for the conservation and improvement of soil fertility are necessary. Xingu, Maraba, and Araguaina have relatively high potential for agricultural land expansion. Sub-region Maraba has large area of steep land.

The forests in the PGC Area are characterized by heterogeneous structures, although there exist high-quality species. Reflecting the pattern of rainfall distribution, the potential growing stock per unit area of the Area is high in the north and gradually declines southeastward.

(3) In general, the so-called social capability -- technical acceptance, production practice, etc. -- in the Area is low, except in some areas in sub-region Castanhal and at relatively large-size farms.

(4) All the sub-regions of the PGC Area are located in areas remote from such central markets as Sao Paulo and Rio de Janeiro. As Belem and Sao Luis are the largest cities within the Area, Castanhal and Bacabal are relatively favorable in terms of local market, compared with other sub-regions. The same thing can also be said with respect to international market. In sub-regions Maraba and Imperatiz, the size of local market which is small at present is expected to be enlarged along with rapid increase in population.

(5) The access of most of the sub-regions to the central markets of Brazil and the world markets have been substantially improved by the construction of such main transport infrastructure as the Transamazonica and Belem-Brasilia highways, and the Carajas railroad. However, with the exception of Bragantina (in Castanhal sub-region) and some other municipalities, the Area is lacking a well-consolidated network of transport infrastructire. As a result, the development in the Area has been limited to the areas along the main roads, and the formation of producing areas has not been efficiently promoted.

(6) The construction of processing and marketing facilities in the Area is also far behind that in the southern states of Brazil. This is, needless to say, closely related to the small size and instability of the production of the Area's agriculture, forestry and livestock sectors. It is observed that those areas close to Belem, Sao Luis and Imperatriz tend to be favorable in processing and marketing facilities, although the situation is dependent on the types of products. The Area is also backward in terms of agricultural cooperative activities, except in some limited zones. This seems to be due to the fact that the number of commercial-product-oriented and medium-size farms, which are the core of agricultural cooperative activities, is still small in the Area.

(7) Some special features of the PGC Area are also observed in its institutional aspect. The Area has plenty of land of which the ownership is still not established. Moreover, the technical

extension services are not sufficiently provided, due mainly to inadequate transport infrastructure and farmers' low technical acceptance capability.

With respect to credit and price policies, preferential treatments have been given for the whole North and Northeast regions including the PGC Area. However, the Area has relative disadvantages due to its timing of development and other specific conditions. For examples, as the Area started to develop at a large scale when Brazil entered a period of credit squeeze, the Area is not favorable in the production of capital-intensive products, and some of the important products of the Area are not familiar to be covered by the present price support system.

10-3 Comments on Preliminary Screening of Priority Products and Necessary Conditions for Development

(1) A preliminary screening of suitable products for the Area was made, based on the development perspective of the Area's agriculture, livestock and forestry sectors (10-1), their surrounding conditions (10-2), and the major characteristics of the products. Of the products which can be produced in the Area, those of high priority are stated in the following together with the major reasons for their selection.

(a) Rice, maize, feijao and cassava which are widely cultivated in all sub-regions, and suitable to the objectives of self-supply of food and increase in the incomes of small- and medium- size farms;

(b) Rubber, cacao, and other perennial crops for the purpose of farmer's immobilization and farm-management stabilization;

(c) Oil palm (Castanhal) and soybean (Imperatriz, Araguaina, Balsas, and the southern part of Bacabal) as newly-emerged commercial crops of relatively high profitability and being suitable to the utilization of local conditions.

(d) Babassu (Bacabal) and Brazil nut (Maraba) which are the Area's special products;

(e) High-quality tropical fruits and pepper suitable to the utilization of the Area's natural conditions (Castanhal);

(f) Fresh vegetables for local markets (Castanhal and Bacabal at present, and Imperatriz, Maraba and Xingu in the future);

(g) Rubber (Imperatriz, Xingu, etc.) and sugarcane as commercial crops, provided that market trend is favorable and production is promoted collectively to some reasonable scale at an area;

(h) Beef cattle utilizing abundant land resource of the Area;

(i) High-quality timber products benefited by the huge forest resources, and trees for wood industry material to be planted correspondingly to the Area's natural and economic conditions.

Needless to say, the above-mentioned products were preliminary selected on the basis of the various conditions which are presently given to the PGC Area. As already referred to, any changes in these conditions will bring about changes in the priority of products. The fact that the emergence of a new soybean variety has made the production of this crop promising in the Area presents a good examle of the impact of the influencing factors on the product selection.

Any favorable changes for the above selected products in their surrounding production conditions are expected to facilitate the achievement of the product screening's objectives.

(2) It is from the above point of view the study team elaborated the following comments on product screening and necessary conditions for the development of the PGC Area's agriculture, livestock and forestry sectors:

(a) Promotion of Basic Food-Crop Production

Rice, maize feijao and cassava were recommended as high priority crops for their suitability to the natural conditions and their wide-spread cultivation as the basic food-crops for large number of small farmers. The objective of the promotion of the production of these four crops is to improve the level of these farmers' living standard. For this purpose, a package of supporting measures including improvement of extension services, activities related to cooperatives and other types of farmers' organizations, and processing and marketing facilities, as well as establishment of land-ownership seems desirable. This policy package is expected to work towards increasing the yield level, and the commercialization rates of these crops.

(b) Farmer's Immobilization

The shifting cultivation system which is presently practiced by large number of farmers in some sub-regions of the PGC Area is said to result in low farm incomes and deterioration of natural environment. Therefore, a transition of these farmers from the shifting cultivation system to a sedentary cultivation system is desirable for increasing their incomes and conserving the Area's natural environment. Some suitable measures for this purpose seem to be (i) reduction of the costs of soil fertility maintenance though research and technical services related to the sedentary, cultivation system, and improvements in farmers' access to current inputs, (ii) establishment of land-ownership, and (iii) financial and technical supports for the introduction of perennial crops.

(c) Strengthening the Competitiveness of Commercial Products

The major commercial products which presently come to attention are (i) crops such as oil palm, soybean and pepper, (ii) local specialities such as babassu and Brazil nut, (iii) beef, and (iv) forest products such as high-quality timber products and other wood material for industries.

Regarding the commercial crops, oil palm is suitable mainly for sub-region Castanhal, and soybean mainly for Araguaina, Imperatriz and Balsas sub-regions. These sub-regions are expected to become producing areas of these two crops. Improvements in the access of cultivators to credits and in processing and marketing will be recommended in addition to suitable measures with respect to seed production, soil fertility maintenance, and cultivation.

For such special products as babassu (Bacabal) and Brazil nut (Maraba), development of new and comprehensive uses and promoting cultivation upon necessity are expected to strengthen the utilization of these precious resources.

The Area, specially in those sub-regions with high land-labor ratios, has high potentials for beef cattle raising. In order to enhance the competitiveness of this product it will be necessary to improve both the productivity of pasturelands and the quality of beef cattle, to improve infrastructure for transportation both within the production area and from the production areas to markets, to plan the future location of slaughterhouses, and to work out a beef cattle production plan for the Area in line with long-term demand and supply forecasts.

Forest resources may be used in two ways depending on the locational features of the areas: as a source for high-quality timber products, or as material for wood industries. In either case, the transport infrastructure needs to be improved, but the former urgently requires quality standardization to be acceptable to overseas markets; and the problems of the latter concern the possibility of establishing pulp mills, alcohol plants, and charcoal-consuming factories close to the forest site.

(d) Environmental Conservation and Integration of Development Policies

Followings are some additional comments related to the development of the PGC Area's agriculture, livestock and forestry sectors.

The first is on harmonization of environmental conservation and development. As previously referred to, in the PGC Area generally land utilization is extensive and land productivity is low. On the other hand, there has been a high pace of conversion of forests into cropping or pasture land, and in some areas this conversion has given an impression of indiscriminate development.

Though development is essential, the most pressing issue in the Area seems to be how to harmonize agricultural land development and environmental conservation. In solving this issue it seems desirable that, on the one hand the productivity of the existing agricultural land be raised as much as possible, and on the other hand priority of new land development be assigned to areas favored by good natural conditions and well-established infrastructure. The so-called priority-region development formula, seems effective in harmonizing development and environmental conservation, as well as allowing for efficient use of financial resources.

Scenes in which forests were burned near the top of mountains and on steep land were also observed during the field observations. Careful considerations seems desirable in choosing the way of land clearance, as the Area belongs to a tropical zone where the rainfall strength is very intense.

The second comment is on the position of the PGC Area in the whole Brazil in terms of commodity production. The selection and production of agriculture, livestock and forest products depend not only on the natural conditions, the level of technology, and various socio-economic conditions but also on institutional factors such as credit and support price policies. One example of the impacts of socio-economic factors including institutional systems on development is seen in the rapid conversion of forests to pastureland along the Belem-Brasilia highway, as induced by improvements in transport infrastructure, low land price, and policy incentives. Some of these areas could be converted to soybean production if soybean price, financing conditions, processing facilities and other surrounding conditions were favorable to this product. As mentioned in the above example, the products to be produced will change considerably according to the series of policies to be taken. In this sense, it will be very important to elaborate, in relation to the national policies, the Area's position in Brazil as a whole as to what kinds and amounts of products are to be expected to the Area.

The third comment is on comprehensive implementation of policy instruments at the regional or sub-regional level. In implementing the policy measures, it is desirable that these measures are well adjusted to suit the specific conditions at the regional or sub-regional level. It is effective that these policy instruments, such as improvement of infrastructure including rural roads, processing and marketing facilities, establishment of landownership, enhancement of technical extension service system, and provision of necessary financial funds are consistently coordinated and implemented.

As the PGC Area has great potential for development, it is hoped that the area will be developed through a carefully-devised program which is based on long-run perspective and ensures optimal utilization of the Area's development potential.

PART Ⅳ

STUDY OF MINERAL RESOURCES DEVELOPMENT

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1. INTRODUCTION

This part of the Phase II Report describes results of the study related to the mineral sector of the Regional Development Plan of the Greater Carajas Program based on the Terms of Reference (TOR) concluded between the Executive Secretariat of the Greater Carajas Program (SE/PGC) and the Japan International Cooperation Agency (JICA)(refer to Annex 1-3 of Part I). The Study corresponds to the Tasks B-1 to B-4 of the said TOR.

1-1 Objectives

This study aims at the identification of the potential of mineral resources in the Greater Carajas Program Area (the PGC Area), especially in its sub-regions such as Serra dos Carajas, Bacaja and Inaja by means of an analytical review of past and current mineral exploration projects carried out by various Brazilian government and private institutions. The Study further aims to make recommendations for future mineral exploration projects in these sub-regions and thereby contribute to the formulation of a comprehensive mineral resources development program in the PGC Area.

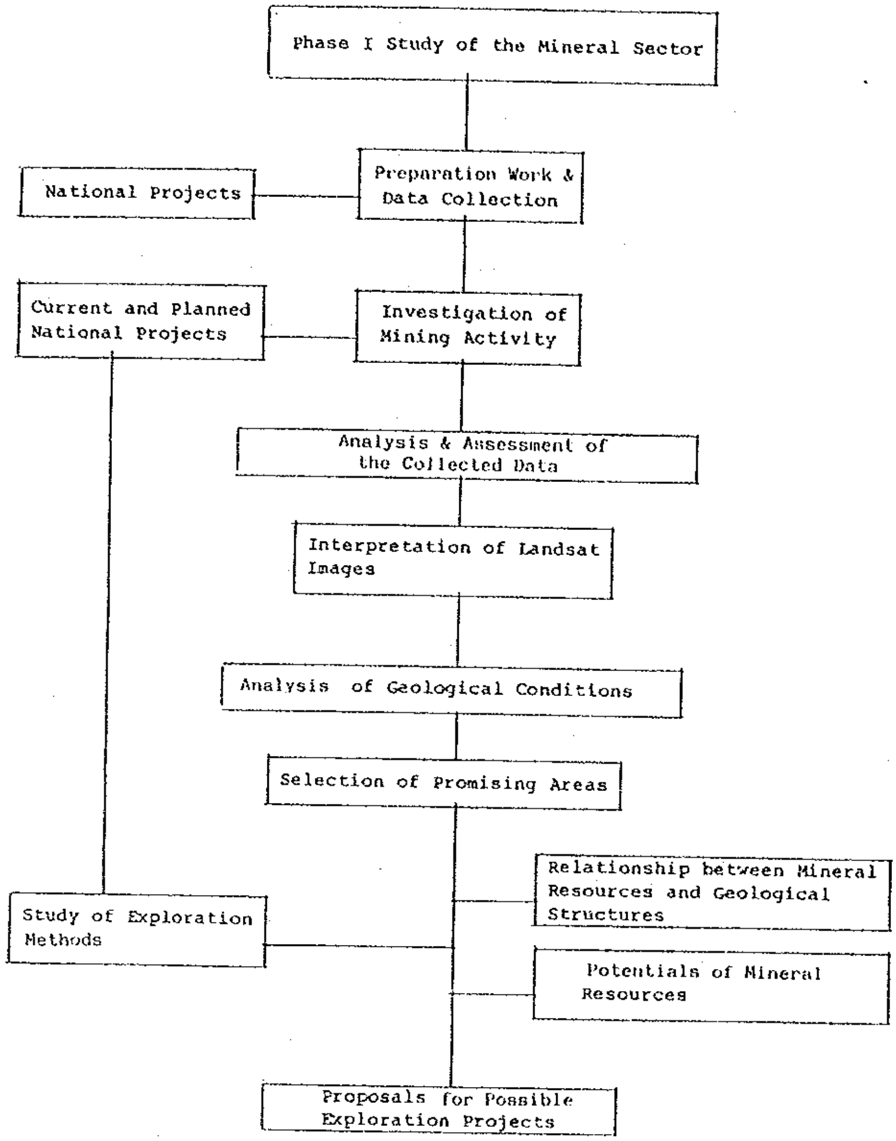
1-2 Methods

In accordance with the said TOR, the Study has been conducted with emphasis on critical analysis and appraisal of existing documents related to mineral exploration in the concerned area, including various survey reports prepared by both government and private institutions. Major study items include:

- Identification and assessment of mineral exploration and mining activities
- Analysis of geological conditions and identification of principal mineral resources in the PGC Area
- Recommendations for future exploration projects

As described in Figure 1-1, the Phase II Study began with data collection by the Study Team which was dispatched to Brazil on July 3, 1984. The Study Team stayed in that country until August 29, 1984 and visited DNPM's (National Department of Mineral Production) Brasilia Headquarter and branch offices in Belem and Sao Paulo, as well as Salobo Copper Deposit and Azul Manganese Deposit in Serra dos Carajas to collect various data and information including Landsat images. Field trips were also made to other two concerned regions, Inaja and Bacaja (see Annex 1-4 of Part I).

Figure 1-1 Flowchart of the Study



1-3 Organization of the Study Report

This part of the Phase II Report consists of five Chapters including Chapter 1, Introduction. Chapter 2 discusses issues related to the production, exploration and development of mineral resources in Brazil, the Amazon Region and the PGC Area in particular. Chapter 3 presents a summary and analysis of geological, geophysical and geochemical surveys conducted in a number of mineral resources exploration projects in the PGC Area, based mainly on the data collected by the Study Team.

The geological analysis presented in Chapter 3 is further elaborated in Chapter 4 in which an overall geological interpretation map compiled on the basis of existing geological maps and the interpretation of Landsat images covering the PGC Area, is presented and explained so as to reveal major geological structures and characteristics of ore deposits in the concerned area. Chapter 5 presents a summary of the subject study and makes recommendations for future exploration projects by outlining areas of high potential and methods of exploration.

2. Mineral Exploration and Mining Activities

This chapter discusses the recent development of the mining industry in Brazil with particular reference to national mineral exploration projects, covering seven principal mineral resources: gold (Au), copper (Cu), tin (Sn), nickel (Ni), manganese (Mn), iron (Fe) and aluminium (Al). The discussion also includes a brief review of the development of mineral exploration and mining activities in the Amazon Region and in the Greater Carajas Program Area (the PGC Area).

2-1 Recent Development of Mineral Production in Brazil

Figure 2-1 shows the development of mineral production in the past three years (1980-1983). The Getulio Vargas Foundation reports that the Brazilian gross national product in 1982 showed an increase of 1.0 - 1.7% over the previous fiscal year. In the mineral industry, the increase ratio was 0.5 - 2.0%, while mineral extraction alone marked an increase of 8.7%.

National Department of Mineral Production (DNPM) reports that the total value of mineral production in Brazil in 1982 was US$6.8 million with an increase of 9.0% over the previous year. Primary minerals and mineral products constituted 25.6% of exports, significantly contributing to the Brazilian economy as a whole.

Petroleum constituted 41.0% of the total mineral production. Gold production was 24.8 tons with an increase of 61.4% over the previous year, owing greatly to the initiative taken by the Government and to the so-called "garimpo (small mines)." In the end of 1982, the Jacobina Gold Mine in the state of Bahia was opened by a joint venture enterprise consisting of two companies: Anglo-American and Bozzano Simonsen. The mine's production capacity is 800 tons/day of crude ore with an estimated total of 1.5 tons/year of gold content. Iron ore production in 1982 was 99.475 million tons, of which 90% were produced by six mining companies including Cia. Vale do Rio Doce (CVRD) which produced a total of 45 million tons. Production of manganese ore in 1982 was 1.7 million tons with a decrease of 8.0% over the previous year. Industria e Comercio de Minerios S.A. (ICOMI) located in the Federal Territory of Amapa produced 54.4% of the total volume. Bauxite production in the same year was 4.2 million tons with a decrease of 9.9% over the previous year, contributing in effect to the stabilization of the mineral's market price. The total volume of bauxite exported in 1982 was 2.901 million tons, which was a decrease of 29.7% over the previous year. The major producer of bauxite was Mineracao Rio do Norte S.A.

In general, Brazil is considered to have ample ore reserves of iron, niobium, bauxite and tantalum to make the country self-sufficient in the supply of these mineral resources, while the known reserves of molybdenum, platinum, silver and copper are considered insufficient. The supply of non-metallics except sulfur and fluorite is also at the self-sufficient level, although energy resources are in short supply, excluding uranium and thorium.

Brazilian trade balance of energy resources in 1982 marked a surplus of over US$778 million as a result of an import restriction imposed by the Government in that year. The trade balance of mineral resources as a whole in 1982 showed a recovery with a deficit of US$ 8,815 million compared to that of US$10,076 million in 1981. The total value of mineral resources exported in 1982 was US$5,116 million, which was an increase of 2.2% over the previous year.

Iron ore accounted for 36.1% (US$1,290 million) of the total exports in 1982, while it constituted 34.7% (US$1,147 million) in the previous year. The market price of iron ore was US$19/ton in 1982 while it was US$17.67/ton in 1981. Steel products and ferro-alloy accounted for 18.8% of the total Brazilian exports.

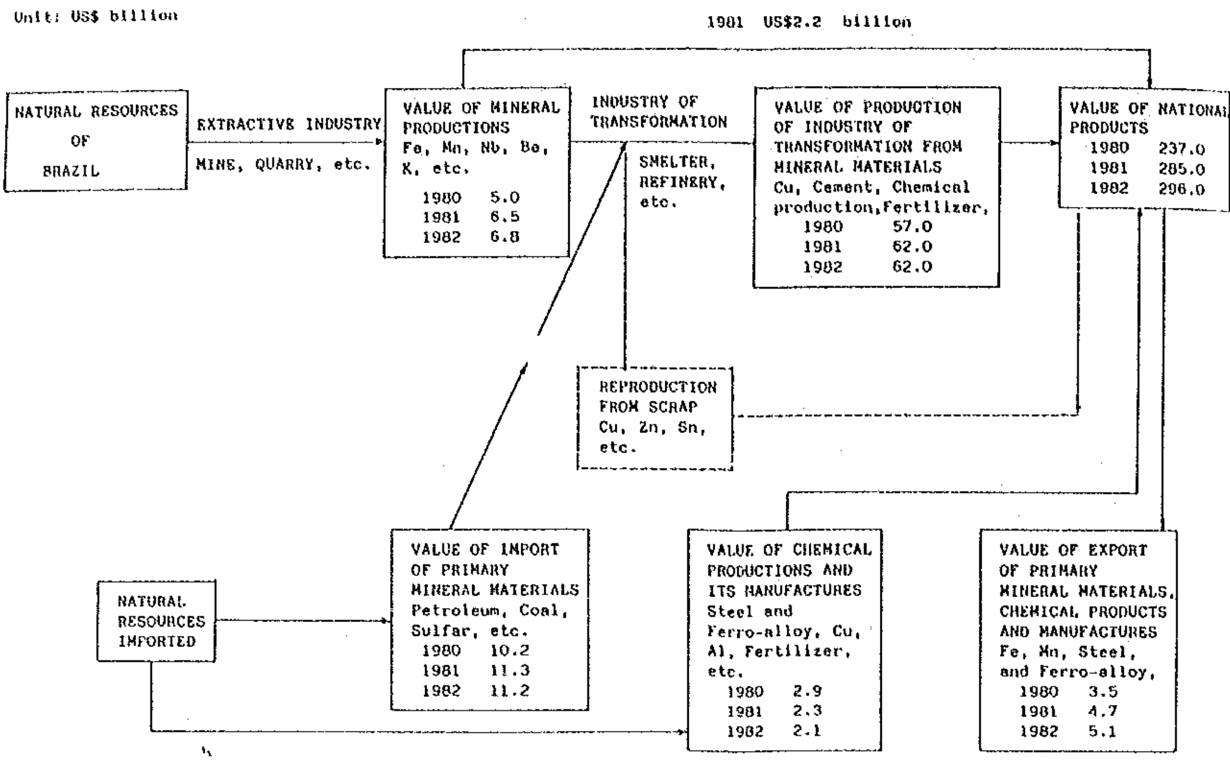
Bauxite and manganese accounted for 1.7% and 1.0% respectively. The export value of bauxite ore in 1982 was US$87 million, showing a decrease of 23.6% over the previous year in which the figure was US$114 million. The export of manganese was also decreased in value with a total of US$47 million in 1982, which was 18.9% less compared to US$58 million in the previous year. Manganese export in 1982 showed a decrease of 16.9% in volume over the previous year and the average market price was also decreased from US$82/ton in 1981 to US$78/ton in 1982. The average market price of bauxite in 1982 was US$30.13/ton while it was US$27.71/ton in the previous year. In 1982, a total of 34 million tons of bauxite ore was produced while the figure was 4.6 million in 1981.

As for petroleum and its processed products, they constituted 80.5% (US$10,705 million) of the total Brazilian imports in 1982, while the ratio was 73.3% (US$11,047 million) in 1981. The total value of fertilizer and sulfur imported in 1982 was US$430 million, of which US$ 130 million were spent for sulfur. The total value of coal imported in 1981 was US$413 million while the figure was decreased to US$358 million in 1982.

Copper import accounted for 80.6% of all the nonferrous metals imported in 1982, showing an increase of 8.6% over the previous year. The total value of copper import in 1982 was US$330 million while the figure was US$304 million in the previous year. It is expected that the commencement of copper production by Caraiba Metais S.A. will significantly reduce the country's dependency of copper supply on foreign countries.

In 1982, a total of Cr$36,279 million (6% increase over the previous year) was collected through the Brazilian tax system known as "IUM (Tax on Mineral Products)." Federal Government received ten percent of the tax revenue while States and Territories received 70%. The remaining 20% was distributed to local municipalities.

Figure 2-1 Development of Mineral Production in Brazil (1980-82)



2-1-1 Production of Principal Mineral Resources and Development Plans

(1) Gold Production and Development Plan

The following table shows the amount of gold produced between 1979 and 1982, indicating the fact that the amount of gold produced in what is called "garimpos (small mines)" was significantly increased in 1980 and it constituted almost 83% of the total gold production in 1982.

(Unit: kg)

	1979	1980	1981	1982
Mine and Dredge	3,333	4,090	4,429	4,859
Garimpos (small mines)	1,128	11,124	10,943	24,908
Total	4,461	15,214	15,372	29,767

Of the total gold production of 29,767 kg in 1982, 63% was produced in the state of Para, 18% in Minas Gerais, 7% in Mato Grosso, 5% in Rondonia and the remaining 7% in other States. While the so-called "garimpeiro" or "gold washers" working in small mines have been the major contributors in the production of gold, mechanical mining of primary and secondary gold ore deposits has been introduced by some mining companies such as Mineracao Morro Velho and Nova Lima in the state of Minas Gerais. Small scale dredge mining was in operation in Minas Gerais by Mineracao Tejucana and Cia. Minas da Passagem e Dragagem Fluvial. The Jacobina Project by Mineracao Morro Velho was put into operation in the state of Bahia in 1982 at an estimated investment of US$80 million for an estimated production of 1.5 tons/year of gold contents.

Production of gold in the Amazon Region is expected to increase in the near future as the Government begins to take control over the "garimpo" activities in the Region and a number of projects related to the production of gold in the Amazon Region are being planned as follows:

Mine/Project (State)	Present Production (ton)	Planned Production (ton)	Start Expected
Morro Velho (MG)	4.0	6.0	1982/1983
Caraiba (BA)	-	2.0	1983
Araci (BA)	-	4.0	1982
Carajas (PA)	-	6.0	1987
Camaqua (RS)	-	0.3	1983
Gurupi (MA)	-	1.5	1984

(2) Copper Production and Development Plan

In 1982, a total of 14,960 tons of copper concentrate (5,000 tons of copper contents) were produced at the Camaqua mine in the state of Rio Grande do Sul. The mine is operated by Financiadora de Insumos Basicos (FIBASE) which is a subsidiary company of the National Bank for Economic and Social Development (BNDES). In the same year, a total of 57,000 tons of copper concentrate (19,000 tons of copper contents) was produced at the Caraiba mine which was opened in 1980. The copper smelter and refinery of Caraiba Metais S.A. at the Camacari petrochemical complex in the state of Bahia produced 9,573 tons of electric copper by refining copper ores mined at the Caraiba and Camaqua copper mines. The following table shows the production of copper between 1979 and 1982.

(Unit: ton)

	1979	1980	1981	1982
Concentrate (Metal cont')	62	402	13,945	24,482
Metal, Primary	-	-	-	9,573
" Secondary	53,100	63,000	45,000	57,000

The copper smelter of Caraiba Metais S.A. began its operation in 1982 with production capacities of 150,000 tons/year of copper, 150,000 tons/year of sulfuric acid, 2,500 tons/year of nickel sulfate, 60 tons/year of selenium, two tons/year of gold, and 20 tons/year of silver, although it is not in full operation at present. It is planned, however, to produce phosphoric acid at an annual production rate of 431,000 tons using sulfuric acid. The smelter consumes 500,000 tons of copper concentrate, of which 165,000 tons are mined at the Jaguarari mine (Caraiba) in the state of Bahia and 35,000 tons at the Camaqua mine while the remaining 300,000 tons are imported.

Eluma Metais S.A. had a plan to build a smelter in the state of Rio Grande do Sul. The plan, however, was changed because of the Government's policy to give priority to the eastern part of the Amazon Region and the smelter was planned to be constructed in Sao Luis in the state of Maranhao. It was planned to produce 150,000 tons/year of copper by importing 60% of copper concentrate to be consumed at the smelter and by introducing advanced refining technology developed by Noranda (Canada). Industria e Comercio de Metais S.A. is reported to have a plan to recover 4,000 tons/year of copper from alloy at the Cacapava smelter in the state of Sao Paulo.

Current copper production plans in the four major copper producing areas are as follows:

165,000 tons/year in Caraiba (BA)
35,000 tons/year in Camaqua (RS)
100,000 tons/year in Mara Rosa (GO)
120,000 tons/year in Carajas (PA)

By 1985, copper production is estimated to reach 100,000 tons/year and the figure will reach 210,000 tons/year by the end of the 1980s. As for investment, a total of US$457 million was allocated for the development of copper production in 1981 while the figure was US$ 469.3 million in 1982. In 1982, DOCEGEO/CVRD reported the existence of 1.2 billion tons of copper ore reserve (0.8 - 1.5% Cu) in the PGC Area and CVRD carried out basic engineering studies for the purpose of producing 120,000 tons/year of copper by investing US$20 million/year between 1982 and 1984. The following table shows chemical composition of copper concentrate produced at a pilot plant in the area:

Cu	40.8%	S	7.9%	Al_2O_3	3.1%
Au	10 g/ton	Fe sulphide	6.9%	CaO	0.6%
Ag	6 g/ton	Fe total	14.3%	MgO	1.2%
Mo	0.27%	SiO_2	15.3%		

In 1982, the Executive Secretariat of the Greater Carajas Program (SE/PGC) adopted Resolution No.9, authorizing mining companies to undertake surveys related to the development of the Salobo copper ore deposit and to participate in related projects.

(3) Tin Production and Development Plan

In 1982, the state of Rondonia was the leading tin producing state in Brazil contributing 64% of the total tin production in that year, followed by Para (19.4%), Amazonas (8.2%), Mato Grosso (6.0%), Goias (1.4%) and Minas Gerais (1.0%). Among many mining groups, "Group Paranapanema" was the leading tin producer with a total production of approximately 3,012 tons which constituted 36.6% of the gross tin production in 1982. Tin has been produced in excess of Brazilian domestic demands. Accordingly, a total of 1,400 tons of tin was exported in 1982. Tin production between 1979 and 1983 is shown in the following table:

(Unit: ton)

	1979	1980	1981	1982	1983
Concentrate (Metal Cont')	7,005	6,930	8,297	8,218	12,700
Metal, Primary	10,133	8,796	7,189	9,298	12,700*

* estimated

Major tin producing companies and their shares of production are as follows:

Companies	Share of Production
Mamore Mineracao e Metalurgia S.A. (Paranapanema)	49.2%
Cia. Estanifera do Brasil - CESBRA (Brascan/British Petroleum)	35.1%
Cia. Amazonense - Cia. Best Metais e Soldas	7.3%
Bera Brasil Metalurgia e Comercio de Metais Ltda. (Brumadinho)	6.3%
Cia. de Estanho Minas Brasil	1.1%
Cia. Industrial Fluminense	1.0%
Mequimbras Metal Quimica Brasileira Ltda.	0.01%

The so-called "Tin Province of Mapuera" is currently considered to be the most promising area for the production of tin. In addition, the following production plans by three mining companies are being considered to reach a target figure of 1,020 tons/year within five years:

Company	Location	Production
Brumadinho/METAGO	Minacu (GO)	15 tons/month
Min. Sao Jose	Sao Felix do Xingu (PA)	50 tons/month
Min. Canopust	Altamira (PA)	20 tons/month

(4) Nickel Production and Development Plan

The following table shows the production of nickel between 1979 and 1982. As shown in the table, nickel production in 1982 was increased by 50% over the previous year. The increase was due mainly to the fact that a new ferro-nickel alloy factory (nickel content: 5,000 tons/year) constructed by Empresa de Desenvolvimento de Recursos Minerais S.A. (CODEMIN) of "Group Hochschild" in the state of Goias (Niquelandia), started its operation with an estimated production capacity of 15,000 tons/year of nickel. In additon, Cia. Morro do Niquel of the same group constructed a ferro-nickel furnace with a production capacity of 2,500 tons/year in the state of Minas Gerais. Cia. Niquel Tocantins of "Group Votorantin" produces 3,562 tons/year of nickel-carbonate in the state of Goias (Niquelandia). Using the nickel-carbonate produced in Niquelandia, 1,338 tons of electric copper are produced in Sao Miguel in the state of Sao Paulo.

(Unit: 1,000 tons)

	1979	1980	1981	1982
Ore Mineral	244.9	43.1	475.9	860.2
Ni-cont' of mineral	2.964	5.838	6.567	14.451
Ni-cont' of carbonate	-	-	0.170	1.661
Ni-electric			0.005	1.338
Ni-cont' of Fe-Ni	2.463	2.504	2.335	3.471

As for nickel production development plans, four projects have been cancelled so far owing to the recent world-wide economic stagnation. However, Metais de Goias S.A. (METAGO) plans to produce some 2,000 tons of metallic nickel in the state of Goias. Sulminas Metal Alloy Ltda. announced a plan to produce 630 tons/year of ferro-nickel in Liberdade in the state of Minas Gerais and BAMINCO/Mineracao e Siderurgia S.A. has a plan to build a new ferro-nickel alloy factory in cooperation with INCO (Canada) and Consorcio da Alemanha Ocidental (West Germany). The new factory will have a production capacity of 55,000 tons/year, of which 80% is for export. Further, Mineracao

Santa Maria Ltda. of "Group Acesita" is reported to have a plan to produce 2,560 tons/year of ferro-nickel alloy in Ipanema in the state of Minas Gerais.

(5) Manganese Production and Development Plan

Manganese ore production showed an increase of 1.5% per year between 1974 and 1981, while steel production and iron alloy production was increased by 8.4% and 12% respectively in the same period. In 1974, a total of 1.7 million of refined manganese ores was produced, of which 89% was exported. As shown in the following table, a total of approximately 1.8 million tons of refined manganese ores was produced in 1981. The export ratio in 1982 was decreased to 62%.

(Unit: 1,000 tons)

	1979	1980	1981	1982
Crude ore	2,809	2,704	3,166	2,900
Refined ore	1,951	2,044	1,835	1,700
Fe-Mn alloy	261	275	251	293

In 1982, Industria e Comercio de Minerais S.A. (ICOMI), which is a joint venture company of ANTUNES/CAEMI (51% share) and Bethlehem Steel (49% share), produced 897,000 tons of manganese. Approximately 20% (184,000 tons) of the total manganese produced by ICOMI was consumed domestically. The domestic production of manganese in 1982 was 1.7 million tons, of which 54.4% was produced by ICOMI while 28.8% was produced by other companies in the state of Minas Gerais and the remaining 16.8% in the states of Bahia and Mato Grosso do Sul.

The table indicates that the production of ferro-manganese (Fe-Mn) alloy in 1982 was increased by 17% over the previous year, while the production of manganese pellets was decreased by 38.3% (100,300 tons). Brazil's production capacity of ferro-manganese alloy is estimated at 321,000 tons/year.

As for current plans for the development of manganese ore production, Mineracao Buritirama Ltda. is reported to have a plan to produce 400,000 tons of manganese ores (lump and concentrated) at the Serra do Buritirama manganese ore deposit which is considered to have 12 million tons of ore reserve. The plan also includes the production of ferro-manganese alloy at an estimated investment of US$4 million.

Cia. Vale do Rio Doce (CVRD) is undertaking a project known as "Projeto Carajas (Carajas Project)" whose major purpose is to develop the Azul manganese deposit in the state of Para by 1985. The Executive Secretariat of the Greater Carajas Program (SE/PGC) has approved to produce one million tons/year of manganese ore at the Azul deposit. CVRD was given authorization by SE/PGC to develop a manganese deposit in the Carajas area at an investment of US$40 - 50 million. Cia. Paulista de Ferro-Ligas announced a plan to build a 7.5 MVA furnace in 1982 for the production of 13,000 tons/year of ferro-manganese alloy, while a similar project in Tres Lagoas in the state of Mato Grosso do Sul planned by Fermats and Associacao da Convap Mineracao e Metamat, was cancelled.

(6) Iron Production and Development Plan

Iron ore is the principal mineral resource in Brazil, constituting 23% of the country's gross mineral production in 1982 (petroleum and natural gas excluded). The following table shows the amounts of iron production between 1979 and 1982.

(Unit: 1,000 tons)

	1979	1980	1981	1982
Iron Ore	96,112	114,692	98,700	99,457
Pellet	19,800	21,600	17,800	15,527

In 1982, Brazil had a capacity of producing 140 million tons/year of iron ore at 116 open-pit mines operated by 60 mining companies. Iron production by the following seven major companies accounted for 95% of the total iron production in 1982:

Companies	Share of Production
Cia. Vale do Rio Doce - CVRD	51%
Mineracoes Brasileiras Reunidas - MBR (CAEMI - US Steel)	17%
Ferteco Mineracao S.A. (Export. Und Bergbau - RFA)	9%
S.A. Mineracao da Trindade (AEBE.D-LU)	8%
Samarco Mineracao S.A. (SAMITRI-UTAH INT)	4%
Cia. Siderurgica Nacional (SIDERBRAS-BR)	4%
Itaminas Comercio de Minerios S.A. (ITAMINAS-BR)	2%
	(Total 95%)

The above seven mining companies had a total of 18 mines (iron pellets were produced in seven mines) in 1982. Table 2-1 shows the amounts of iron ore and pellets produced, exported and domestically consumed between 1979 and 1982.

Table 2-1 Production, Export and Domestic Consumption of Iron Ore in Brazil

(Unit: 1,000 tons)

	Production		Export		Domestic Consumption
	Crude Ore	Pellets	Crude Ore	Pellets	Crude Ore
1979	96,112	19,800	59,675	15,913	35,706
1980	114,692	21,600	61,001	17,957	38,616
1981	98,700	17,800	64,913	20,885	33,300
1982	99,457	15,527	65,644	18,763	33,400

Source: SUMARIO MINERAL, DNPM, 1982/83

Iron ore is one of the most important mineral resources for Brazil to maintain its economy which is dependent on the export of primary mineral resources.

As for current and future development plans related to the production of iron ore, CVRD's project known as "Projeto Ferro Carajas (Carajas Iron Project)" in the state of Para is the main project of the 1980s. The N4E ore body in the northern range of Serra Norte with an estimated iron ore reserve of 1.2 billion tons shall be vigorously developed to exploit the valuable mineral resource in the area (83% sinter feed ore and 17% massive ore). In the Project, the iron ore mined at the N4E ore deposit is planned to be transported via railway to Ponta da Madeira. By the end of 1981, a total of US$619 million was invested into the Project, which is approximately 18% of the total budget covering all the required expenditures for the construction of production facilities, a railway and a shipping port.

In 1981, a series of agreements were signed between CVRD and foreign enterprises to export a total of 25 million tons/year of iron ore. Production at the N4E iron ore deposit is expected to reach 15 million tons/year by 1985 and 35 million tons/year by the end of the 1980s. The Project is scheduled to be completed by July 1986. Major events took place so far include: (a) completion of a railroad with a total length of approximately 500 km between Sao Luis and Maraba in October, 1984; (b) issuance of US$18 million debenture; and (c) creation of 13,000 jobs. The following table shows investments to and completion ratios of sub-programs of the Carajas Iron Project.

(Unit: US$million)

Items	Total Investment	Value in 1983	Executed to 1983	Percent of Execution (%)
Mine	466	46	201	43
Railroad	1,496	206	816	55
Port	182	29	79	43
Center	153	13	51	33
Infrastructure	73	3	62	85
Engineering	136	10	131	96
Administration/Supervision	447	51	267	60
Pre-Operation	56	3	13	23
Contingency	95	0	0	0
Total	3,104	361	1,620	52

CVRD is also undertaking another project in the Timbopeba-Capanema area in the state of Minas Gerais. The project aimed at producing 26.5 million tons/year of iron ore with an investment of US$225 million by 1983. In addition, CVRD and Kawasaki Steel Corp. (of Japan) jointly developed the Capanema iron mine in Ouro Preto in the state of Minas Gerais in 1982 and produced 1.7 million tons of iron ore in that year. The production was expected to reach 10.5 - 11.5 million tons/year by 1983.

(7) Aluminium Production and Development Plan

Bauxite production before 1978 mainly took place in the Centro Sul area. Most of the bauxite mined there was used to produce alumina from which aluminium is produced. In 1979, a new bauxite deposit was developed in the state of Para in a project known as "Projeto Trombetas" by Mineracao Rio do Norte S.A. (MRN). The following table shows the amounts of bauxite, alumina, and primary and secondary aluminium produced between 1979 and 1982:

(Unit: 1,000 tons)

	1979	1980	1981	1982
Bauxite	2,160.0	4,696.4	4,662.6	4,200.0
Alumina	449.1	492.7	519.0	585.0
Primary aluminium	238.3	260.6	256.4	299.1
Secondary aluminium	37.9	53.2	32.0	47.1

Most of the aluminium producing companies in Brazil use domestic bauxite and refine it into aluminium except ALUNORDESTE which uses imported alumina. In 1983, a total of 414,000 tons of aluminium was produced by the following major companies:

Companies	Production (tons/year)	Group	Location
Cia. Brasileira de Aluminio-CBA	120,000	Votorantim	Mairinque (SP)
Aluminio do Brazil S.A.	60,000	ALCAN	Saramenha (MG)
Aluminio do Brasil Nordeste S.A.	58,000	ALCAN	Aratu (BA)
Cia. Mineira de Aluminio - ALCOMINAS	90,000	ALCOA	Hamna P. de Caldas (MG)
Valesul Aluminio S.A.	86,000	CVRD	Billiton Santa Cruz (RJ)

In 1981, production of aluminium was largely limited to the three major groups known as ALCAN, ALCOMINAS and CBA whose production facilities were located in the Centro Sul area. In 1982, a total of 585,000 tons of alumina was produced, of which 120,000 tons were produced by ALCAN, 215,000 tons by ALCOMINAS and 250,000 tons by CBA.

As for bauxite, a total of 4.2 million tons was produced in 1982, of which 69% was produced in Trombetas. Bauxite production in the Amazon Region has been doubled in response to increased demands made primarily by ALUNORTE and Aluminio do Maranhao S.A. (ALUMAR).

Production of primary aluminium in 1982 was 299,000 tons with an increase of 16.8% over the previous year. ALCAN produced 29.6% of the total amount, ALCOMINAS, 30%; CBA, 32.3%; and VALESUL, 8.1%. VALESUL started its production of aluminium in Rio de Janeiro and produced 84,900 tons in 1983.

As for future production plans, ALCOA is reported to have a plan to produce five million tons/year of bauxite in Trombetas. By the end of the 1980s, alumina production in the Amazon Region is expected to increase up to 3.6 million tons/year, which is approximately 83% of the estimated total alumina production in Brazil. As for bauxite, Brazil needs to produce 15 million tons/year of bauxite ore by the end of 1980s and 87% of this amount is expected to be produced in the Amazon Region. In the meantime, a joint venture project of VALESUR and Nippon Amazon Aluminium Co., Ltd. (NAAC) known as "Projeto ALUNORTE" whose major purpose was to produce 6 - 10 million tons/year of bauxite, was postponed since a concurrent plan to produce 800,000 tons/year of alumina between 1986 and 1989 was also postponed.

Mineracao Rio do Norte (MRN) is reported to have a plan to extend its bauxite production up to 4.7 million tons/year, of which 1.2 million tons/year are required for a new project by Aluminio do Maranhao S.A. (ALUMAR, 40% share by Billiton) which was scheduled to be implemented from 1984. The ALUMAR project consists of a program to construct an alumina factory with a production capacity of 500,000 tons/year in Sao Luis in the state of Maranhao. ALCOA Mineracao S.A., which is a subsidiary of ALUMAR, plans to produce four million tons/year of bauxite by 1988 at the Trombetas ore deposit which is estimated to have a total of 452 million tons of bauxite ore reserve. ALCOA plans to invest US$ one billion to produce 500,000 tons/year of alumina and 100,000 tons/year of aluminium in 1984. By 1987, ALCOA intends to increase its production up to one million tons/year of alumina and 150,000 tons/year of aluminium, and the figures will be further increased to 1.5 million tons/year and 300,000 tons/year respectively in 1989.

In 1982, MRN decreased its bauxite production down to 2.8 million tons/year from the production of 3.35 million tons in the previous year. As for alumina and primary aluminium production, a joint venture project by ALBRAS (Aluminio Brasileiro S.A.) and ALUNORTE (60.8% share by VALENORTE and 39.2% share by NAAC) to construct an aluminium factory in Barcarena in the state of Para is underway. The project aims at producing 600,000 tons/year of alumina and 75,000 tons/year of aluminium by 1986. The production will be further increased up to 800,000 tons/year of alumina by 1986 and 320,000 tons/year of aluminium by 1989.

Aluminio do Nordeste S.A. and Wereinigte Aluminium Werke A.G. (VAW) of West Germany jointly plan to produce 50,000 tons/year of aluminium in 1985 and 81,000 tons/year by 1989. "Group Votorantin" plans to construct an aluminium factory with a production capacity of 200,000 tons/year at an investment of US$200 million. The new factory will be constructed in Paragominas in the state of Para by 1988.

2-1-2 National Programs related to Mineral Exploration

National Department of Mineral Production (DNPM) is responsible for developing and implementing basic survey programs related to mineral exploration and the following surveys have either been carried out or being planned by DNPM:

(1) Geological Survey (Brazil)

(a) Geological exploration survey since 1974 for the compilation of geologic maps at a scale of 1:1,000,000.

(b) Geological reconnaissance survey for the compilation of geologic maps at a scale of 1:250,000.

(c) Semi-detailed geological survey for the compilation of geologic maps at scales of 1:100,000 and 1:50,000.

(d) Aerogeophysical survey for reconnaissance purposes by means of magnetometry and radiometry.

(2) Sub-Programs for the Prospecting and Evaluation of Ore Minerals

(a) Coal

(b) Underground water

(c) Metallic minerals

(d) Non-metallic minerals

(e) Ground geophysical survey

(f) Geochemical prospecting

(3) Programs for the Development of Mineral Technology:

Studies related to ore dressing are carried out by the Center for Mineral Technology (CETEM). DNPM integrates mineral technology developed by National System for Scientific Mineral Technology (SNCTM).

(4) Program related to the Compilation of Metallogenic Maps and Provisional Maps for the Planning and Exploration of Mineral Resources:

DNPM started the program to compile metallogenic maps and provisional maps to assist national and private mineral exploration projects. Following maps covering the areas (priority areas) shown in Figure 2-2 are compiled on the basis of the geologic, aero-geophysical and geochemical data accumulated in the past fifteen years:

(a) Metallogenic maps at a scale of 1:250,000, incorporating geological, geophysical and geochemical data related to ore minerals in selected areas.

(b) Provisional maps at a scale of 1:250,000 to assist exploration and investment planning.

DNPM's budgets in each of the above programs is shown in Figure 2-3. Tables 2-2 gives a breakdown of the investment and Table 2-3 shows the allocation of DNPM's budgets to each program. Table 2-4 gives a breakdown of Basic Geologic Mapping Projects carried out from 1970 to 1980.

Figure 2-2 Priority Sheet for the Compilation of Metallogenetic Maps and Provisional Maps for Planning and Exploration of Mineral Resources

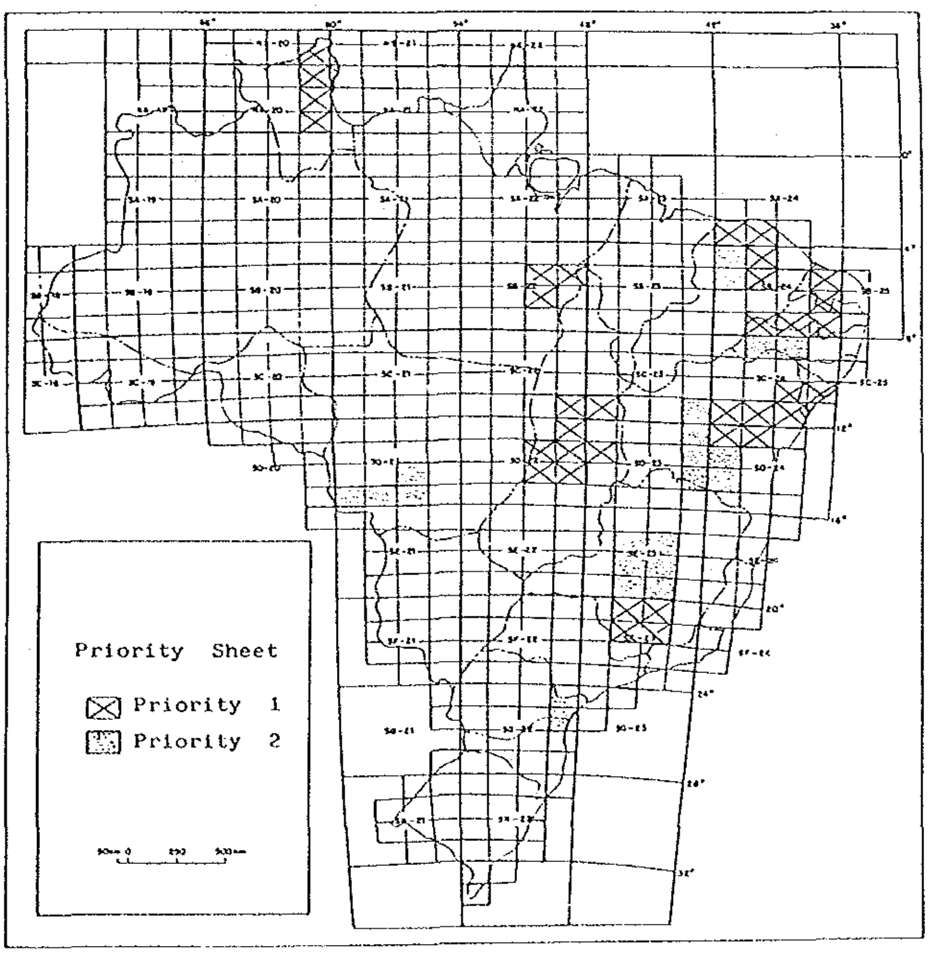


Figure 2-3 Transition of DNPM's Budgets for Different Types of Project

Cr$million (base=1980)

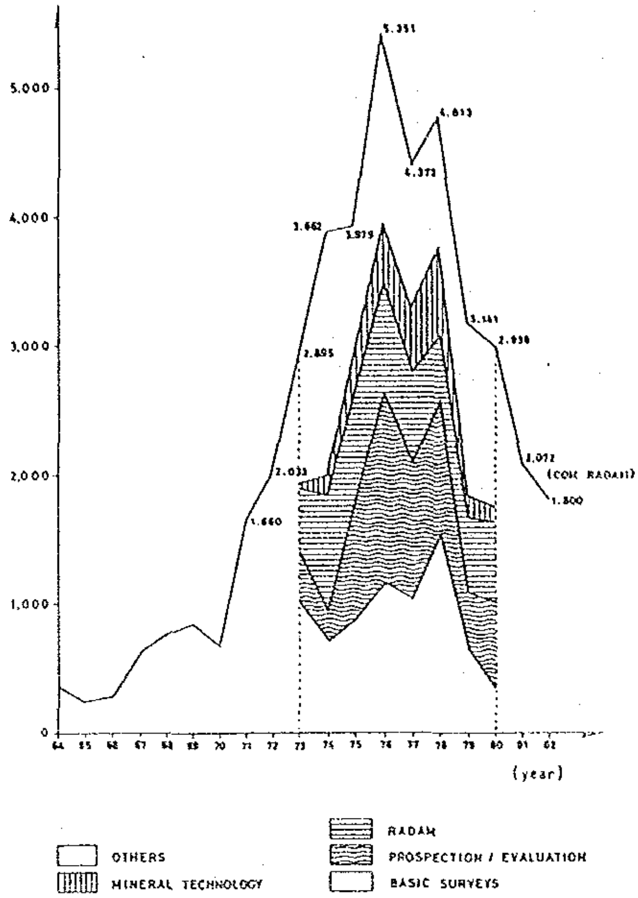


Table 2-2 Breakdown of DNPM's Investments (1973-1980)

Cr$million, value constant=1980

	73	74	75	76	77	78	79	80
1) Basic Geol. Survey	1,012,540	717,431	905,485	1,155,916	1,033,969	1,597,191	678,357	355,111
1:1,000,000	280,969	90,735	6,623	-	-	-	-	-
1:250,000	457,023	379,306	501,114	491,360	229,097	182,669	117,956	95,028
1:100,000/1:50,000	29,935	28,615	99,646	234,819	471,550	721,892	366,699	247,466
Aerogeophysics	244,613	218,775	298,102	429,736	333,322	692,630	193,702	12,617
2) Prosp./Evaluation	398,286	247,213	959,955	1,750,071	1,063,765	1,065,346	423,675	642,531
Coal	283,378	177,119	506,627	661,348	328,081	102,020	51,314	479,098
Underground Water	37,900	12,182	12,093	36,340	18,429	47,570	42,141	29,946
Metals	70,742	28,956	259,446	617,866	448,409	510,359	199,275	69,217
Non-metals	964	8,426	80,748	138,909	62,150	65,709	16,898	1,328
Geophysics Terr.	-	-	52,859	144,941	104,874	189,807	53,543	51,063
Geochemistry	5,301	20,530	48,182	150,508	101,822	149,881	60,505	11,079
3) RADAM Brasilo	490,360	891,928	814,444	535,707	680,900	499,715	610,248	587,880
4) Tec. Mineral	30,431	101,947	308,670	412,941	493,202	680,471	143,452	111,051
5) Others	964,760	1,905,310	987,517	1,495,585	1,106,968	974,148	1,289,404	1,241,675
TOTAL	2,896,377	3,863,830	3,976,071	5,350,301	4,378,805	4,816,871	3,145,136	2,930,248

Source: DNPM

Table 2-3 Percentage of Each Program in DNPM's Budget

Unit: %

PROGRAM \ YEAR	73	74	75	76	77	78	79	80
1. Basic Survey	35	19	23	22	24	33	22	12
2. Prospection/Evaluation	14	6	24	33	24	22	13	22
3. RADAM	17	23	20	10	16	10	19	20
4. Mineral Technology	1	3	8	8	11	14	5	4
5. Others	33	49	25	27	25	21	41	42

Source: DNPM

Table 2-4 Basic Geologic Mapping Projects

Year	Scale 1:500,000 Km^2	Scale 1:250,000 Km^2	Scale 1:100,000 Km^2	Scale 1:50,000 Km^2	Scale 1:25,000 Km^2	Mapping Total Km^2	Route Mapping Km	Outcrop Survey
1970	-	26,537	66,244	15,491	-	108,272	41,206	7,217
1971	-	100,225	36,549	20,531	-	157,305	116,218	14,272
1972	-	650,780	61,502	9,173	-	721,455	214,945	25,452
1973	237,775	635,501	7,000	819	-	881,095	150,726	20,665
1974	72,000	348,202	4,670	9,807	-	434,679	67,136	6,711
1975	9,000	455,415	17,476	9,132	-	491,023	81,700	12,136
1976	-	331,083	30,912	26,240	-	388,235	260,055	32,577
1977	-	125,826	17,125	18,400	-	161,351	118,721	25,315
1978	-	28,370	66,578	43,307	125	138,380	56,354	34,669
1979	-	70,000	35,646	11,445	-	117,091	48,706	16,392
1980	-	21,585	33,950	6,310	-	61,845	12,541	6,562
TOTAL	318,775	2,793,524	377,652	170,655	125	3,660,731	1,168,308	201,968
% of the country		32.6 %	4.2 %	2.0 %				

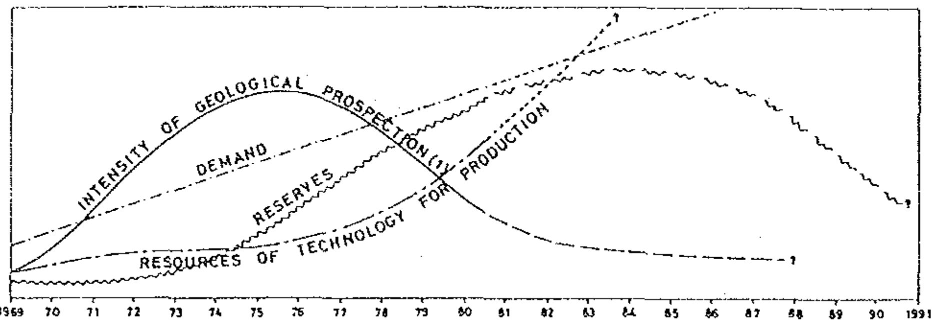
Source: Report of CPRM, 1980

2-1-3 Trends in the Brazilian Mineral Sector

Recent trends related to the development of mineral resources in Brazil are shown in Figure 2-4. As shown in the figure, technological resources for mineral production and demands for minerals are on the increase while ore reserves are expected to decrease in proportion to the intensity of geological prospecting which began to decrease around 1976. The figure indicates that geological surveys must be carried out continuously to maintain a certain amount of known ore reserve at any time.

Other matters of concern in respect to mineral prospecting are that government budgets for basic geological survey projects are decreasing and that budgets for special mineral prospecting projects are almost none. Both government and private investments in the past 12 years (1968 - 1980) are shown in Table 2-5.

Figure 2-4 Trends in the Brazilian Mineral Sector



1. (1) Evaluated by number of geologists in activity of geological survey.
2. Others curves based in date of Anuário Estatístico Brasileiro, Anuário Mineral Brasileiro and others sources.

Source: Braun, O.P.E. et al., Ciências da Terra, No.2, pp.61-70, 1982.

Table 2-5 Investments for Mineral Exploration (1968/80)

US$ thousand

SUBSTANCES \ YEAR	1968/69	1970/71	1972/73	1974/75	1976/77	SUBTOTAL	1978/80	TOTAL
GOVERNMENT : FEDERAL & STATE								
Petroleum/Gas	160,977	182,156	237,048	502,724	896,131	1,979,036	1,462,857	3,441,893
Uranium	1,846	6,593	13,265	23,689	44,190	89,583	83,500	173,083
Other Substances	13,844	22,832	54,371	108,474	152,632	352,153	325,714	677,867
SUB-TOTAL	176,667	211,581	304,684	634,887	1,092,953	2,420,772	1,872,071	4,292,843
PRIVATE								
SUB-TOTAL	NC	2,934	29,019	30,307	63,568	125,828	296,104	421,932
TOTAL INVESTMENTS								
T O T A L	176,667	214,515	333,703	665,194	1,156,521	2,546,600	2,168,175	4,714,775

Source: CPRM

Note: Above figures include investments for Projeto RADAM

2-1-4 Investment Plans

The total amount of investments in the mining industry is expected to reach approximately US$17.8 billion in the 1980s, of which 56% will be distributed to 88 mining and exploration projects and 44% to 23 metallurgical projects. As for the investment in the mining and exploration projects, 30% of the money will be allocated to a project for the development of iron, bauxite, nickel, copper, manganese and gold in Serra dos Carajas by Cia. Vale do Rio Doce (CVRD).

Table 2-6 shows distribution of the investment to 20 States in five Regions. Tables 2-7 and 2-8 indicate budget allocation for the development of major mineral resources. As shown in Table 2-6, 44.6% of the total investment will be allocated to the state of Para in the Northern Region, which is more than the total amount allocated to the North-Eastern Region.

In terms of employment opportunity, more than 61,000 jobs are expected to be created by the planned projects in the 1980s.

Table 2-6 Regional Investment Plan for the Mineral Industry in Brazil (1980-1990)

US$million - 1981

	Mining	Metallurgy
Northern Region	5,590.482	2,377.262
Pará	5,586.942	2,377.262
Rondonia	3.540	-
Central-Western Region	630.535	116.787
Mato Grosso	4.408	-
Distrito Federal	15.857	-
Goiás	610.270 (estimate)	116.787
North-Eastern Region	2,191.037	4,240.448
Alagoas	10.766	-
Bahia	1,444.525	1,391.313
Paraiba	98.089	-
Piaui	1.100	-
Pernambuco	108.079	659.130
Maranhão	-	2,190.005
Rio Grande do Norte	52.923	-
Sergipe	456.630	-
Ceará	18.925	
South-Eastern Region	948.528	498.795
Minas Gerais	944.061	84.314
Rio de Janeiro	1.076	243.767
São Paulo	3.391	170.714
Southern Region	677.865	-
Paraná	35.897	-
Santa Catarina	344.157	-
Rio Grande do Sul	297.811	555.803
Total	10,038.447	7,789.095

Source: INVESTIMENTOS: *PROJETOS DE MINERACÃO E* METALURGIA - 1982, DNPM (Mining) CONSIDER (Metallurgy)

Table 2-7 Item-wise Breakdown of Investment Plan (1980-1990)

Mineral	Investment US$ million-1981	
	Mining	Metallurgy
Total	10,038.447	7,789.095
Aluminium	318.900	5,965.673
Copper	3,195.272	1,683.162
Iron	4,478.616	-
Coal	489.412	-
Phosphorus	413.559	-
Sulfur	253.720	-
Limestone	251.314	-
Gold	159.662	-
Potassium	123.972	-
Nickel	28.260	81.170
Kaolin	96.528	-
Titanium	62.528	-
Zinc	15.020	34.889
Pyrite	34.359	-
Manganese	30.000	-
Tin	18.114	-
Others	68.905	24.201

Source: INVESTIMENTOS: PROJETOS DE MINERACÃO E METALURGIA - 1982
DNPM (Mining)
CONSIDER (Metallurgy)

Table 2-8 Investments for Non-ferrous Metals

US$ million=1981

	Investment	Investments										
		Total	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
I. Aluminium													
1. Projects approved	3,116.3	2,591.3	345.7	421.4	465.2	397.0	195.8	263.5	273.4	173.2	44.2	11.9	-
2. Projects studied	2,590.3	2,590.3	-	89.0	307.0	421.0	610.3	595.2	437.7	130.1	-	-	-
II. Copper													
1. Projects approved	1,374.7	927.5	205.4	90.8	152.2	160.2	141.6	8.4	34.4	34.4	10.0	45.0	45.1
III. Zinc													
1. Projects approved	53.2	31.7	5.3	19.4	7.0	-	-	-	-	-	-	-	-
2. Projects studied	15.0	15.0	-	1.5	5.3	5.2	3.0	-	-	-	-	-	-
IV. Magnesium													
1. Projects approved	20.0	15.9	15.9	-	-	-	-	-	-	-	-	-	-
V. Tantalum													
1. Projects approved	4.2	4.2	-	4.2	-	-	-	-	-	-	-	-	-
VI. Cobalt													
1. Projects approved	31.0	31.0	3.1	10.8	10.8	6.3	-	-	-	-	-	-	-
VII. Nickel													
1. Projects approved	100.0	51.7	30.8	20.9	-	-	-	-	-	-	-	-	-
TOTAL													
1. Projects approved	4,669.1	3,653.3	606.2	567.5	635.2	563.5	337.4	271.9	307.8	207.6	54.2	56.9	45.1
2. Projects studied	2,605.3	2,605.3	-	90.5	312.3	426.2	613.3	595.2	437.7	130.1	-	-	-
3. Total	7,304.4	6,258.6	606.2	658.0	947.5	989.7	950.7	867.1	745.5	337.7	54.2	56.9	45.1

Source: CONSIDER - ANUÁRIO ESTATÍSTICO - 1982

2-1-5 Principal Mining Organizations in Brazil

As noted before, DNPM is the principal government organization that is responsible for the administration of mining-related projects in Brazil. In 1979, the Mineral Technology Coordination Agency (CTM) was established by the National Council for the Development of Science and Technology (CNPq) to undertake research and investigation related to technological aspects of mining activity.

According to the statistics compiled by these agencies, 37% of the gross mineral production (PMB: Producao Minerais Bruto) is accounted for by foreign or foreign affiliated enterprises while 58% is by Brazilian enterprises. As for non-ferrous metals, the production of niobium, gold, lead, nickel, silver and beryllium is dominated by foreign capital while the production of cassiterite, chromite, zinc and tungusten is dominated by national capital. The production of asbestos is in principle dominated by foreign capital.

As shown in the following table, a total of 25.93% of PMB in 1977 was accounted for by 25 major foreign enterprises operating in Brazil, while Brazilian principal enterprises accounted for 18.79% (private) and 16.99% (government). The 50 major enterprises listed in the table accounted for 61.5% of PMB in 1977.

Table 2-9 50 Major Mining Groups and Their PMB Contribution Ratios (1977)

National (Private)	%PMB	National (Government)	%PMB	Foreign	%PMB
1. Votorantin	5.44	1. CVRD	14.01	1. Consórcio MBR	5.32
2. Magnesita	1.79	2. Sidebrás (CSN)	2.72	2. Aberb (Samitri/Samarco)	2.16
3. Paraiso	1.23	3. Gov. Est. RS (CRM)	0.26	3. Export. Und. Bergbau (Ferteco)	2.05
4. João Santos	1.22			4. Union Oil (CBMM)	1.96
5. Paranapanema	1.22		16.93	5. Hochschild (Excibra)	1.82
6. José Carvalho	0.94			6. Bethlehem Steel (Icomi)	1.80
7. Carb. Metropolitana	0.74			7. *Bunge y Born (Serrana)*	0.94
8. Freitas	0.67			8. Anglo-American (Morro Velho)	0.93
9. Brumadinho	0.66			9. Lafarge/Lone Star	0.86
10. Itaminas (4)	0.58			10. Saint-Gobain (Sama/Sta. Marina)	0.78
11. ICAL (4)	0.46			11. Eternit (SAMA)	0.76
12. Vontobel (4)	0.43			12. Italcementi (Sta. Rita)	0.67
13. Tomás Salustino	0.41			13. Holderbank (CIMINAS)	0.66
14. Lima (4)	0.40			14. Brascan	0.65
15. Matarazzo	0.39			15. Intern. Muller	0.61
16. *Orlando Machado (4)*	0.36			16. Imetal (Plumbum)	0.54
17. Catão	0.35			17. U.S.Steel (Meridional)	0.50
18. Camargo Corrêa	0.33			18. Nestlé (Minalba)	0.49
19. Grupo Bravo (4)	0.31			19. Union Minière (Tejucana)	0.48
20. Cauê	0.30			20. UBS/Blue Circle (Pedra do Sino)	0.36
21. Emicon (4)	0.29			21. D.K.Ludwig (Caulim da Amazonia)	0.34
22. Copelmi	0.27			22. Dow Chemical	0.33
	18.79			23. General Electric (Samarco)	0.32
				24. Engelhard Min. (*Mitra/Mipriza*)	0.30
				25. Champalimaud (Soeicom)	0.30
					25.93

Source: CNPq/CTM (DNPM)

2-2 Development of the Mining Industry in the Amazon Region

In the past, all the information related to mineral resources in the Amazon Region were brought only by local prospectors known as "garimpeiro" and occasional travellers or explorers.

The Region began to attract attention in the early 1540s with the so-called "discovery of fantastic El Dorado" by the navigator Francisco Orellana. The legendary story of "Paraupava" - a mystical legend in which a great river appears from the midst of the country with infinite reserves of gold and jewelry, attracted "bandeirantes (prospectors)" to the northern interior of the Amazon Region. Although "Pirapitinga" described in the Indian story was not discovered, prospectors opened up the middle-west route of Brazil, crossing over Araguaia and reaching to Amazon. This is the period known as "Paraupava."

In the 19th century, Spix, Martius, Derby, Agassiz, Humboldt and other naturalists and scientists from the European and American continents began to explore the Amazon Region and paid particular attention to the Region's enormous potential of natural resources. In the early 20th century, Brazilian scientists devoted to the development of mineral resources in Brazil were organized into what was then known as the Brazilian Geological and Mineral Service (SGMB) which later developed into DNPM, and embarked on systematic exploration of valleys and rivers of the Amazon Region. The major purpose of the exploration was to find areas most suitable for the exploitation of coal and petroleum.

In the 1940s with the escalation of World War II, great attention was paid to mineral resources in the states of Minas Gerais and Goias and in the 1950s, giant multinational companies began to explore the Amazon Region. These multinational companies, however, were not able to obtain in-depth data to embark on any substantial development of underground resources.

The exploration of petroleum in the Region was initiated by SGMB and the National Council of Petroleum (NCP) in the 1920s. In 1955, the Nova Olinda oil field was discovered following the establishment of PETROBRAS in the mid-1950s. The discovery activated the development of petroleum in Brazil.

During the same period, "Group CAEMI" established Industria e Comercio de Minerios (ICOMI) in cooperation with Bethlehem Steel and started to mine manganese ore at the Serra de Navio manganese deposit in the territory of Amapa. Basic field surveys including aerophotogrammetry were carried out in a project known as "Projeto Araguaia (the Araguaia Project)" under the supervision of DNPM, covering the central part of the state of Goias and the southeastern part of the state of Para.

During the 1950s and 1960s, "garimpeiros" played a major role in the development of mineral resources in the areas known as "Provincia Estanifera de Rondonia (Tin Province of Rondonia)" and "Provincia

Aurifera do Medio Tapajos (Gold Province of Central Tapajos)." In the middle of the 1960s, bauxite was discovered in Trombetas.

Union Carbide and United States Steel jointly embarked on a systematic exploration of mineral resources and discovered a manganese ore deposit in Sereno near Maraba in 1966. It was the first discovery of mineral resources in the so-called "Mineral Province of Carajas." In the following year, iron ore deposits and manganese ore deposits were discovered in Serra dos Carajas and Serra Buritirama respectively. These discoveries significantly accelerated mineral exploration activities in the Amazon Region.

Major progress in the development of mineral resources took place during the 1970s when DNPM carried out a national project known as "Projeto RADAM." During the same period, Cia. de Pesquisa de Recursos Minerais (CPRM) and CVRD carried out basic geological surveys under the patronage of DNPM mainly and the Superintendency for the Development of Amazonia (SUDAM). Major mineral resources developed in recent years include the followings:

- Bauxite in Paragominas by Rio Tinto Zinc (RTZ) and CVRD.
- Bauxite in Almeirim by CVRD.
- Kaolin in Jari by Group Ludwig.
- Manganese in Azul by CVRD.
- Kaolin in Capim by CPRM and Group Mendes Junior.
- Nickel in Carajas by INCO and CVRD.
- Cassiterite in Xingu by Promix and CVRD.
- Gold in Carajas by diggers and CVRD.
- Cassiterite in Surucucus by DNPM in Projeto RADAM.
- Copper in Carajas by CVRD.

Table 2-10 shows the dates and methods of 14 major discoveries of mineral ore deposits between 1966 and 1978 and Table 2-11 is a list of principal discoveries of mineral resources since 1612.

Table 2-10 Survey Methods and Factors of Discovery of Mineral Ore Deposits in the Carajas Mineral Province

Deposit	Date	Survey Methods and Factors of Discovery
Manganese of Sereno	1966	Reconnaissance geology/Lucky
Iron of Carajas	1967	Lucky/Reconnaissance geology/Photo-interpretation
Manganese of Buritirama	1967	Reconnaissance geology/Photo-interpretation/Lucky
Manganese of Azul	1971	Lucky/Reconnaissance geology
Nickel of Onça	1974	Photo-Interp./Reconnais. geology/Geochem-soil/Lucky
Cassiterite of Antonio Vicente	1974	Lucky/Geochem.-stream sedim./Reconnais.geology/Aeromagne
Nickel of Vermelho	1974	Photo-interp./Lucky/Reconnais.geology/Geochem.-soil
Copper of Bahia	1974	Geochem.-stream sedim./Reconnais.geology/Lucky
Bauxite of Carajas	1974	Lucky/Geochem.-soil
Copper of MM1	1976	Lucky/Geochem.-soil/Reconnais.geology
Gold of Andorinhas	1976	Lucky/Geochem.-rock/Reconnais.geology
Copper of Salobo	1977	Geochem.-stream sedim./Reconnais.geology/Lucky
Gold of Gradaus	1977	Correlation of geology/Lucky/Reconnais.geology/Geochem.-conc.
Cassiterite of Gradaus	1978	Photo-interp./Geochem.-conc./Reconnais.geology/Lucky

Source: AMAZONIA by BRENO AUGUSTO DOS SANTOS,1982

Table 2-11 Principal Discoveries of Minerals in the Amazon Region

Year	Location	Mineral	Discoverer
1612	Gurupi (PA,MA)	Gold	Garimpeiros
1855	Calçoene (AP)	Gold	Garimpeiros
1912	Maú-Tacutú (RR)	Diamond	Garimpeiros
1915	Alto Solimões (AM)	Lignite	
1937	Araguaia-Tocantins (PA)	Diamond	Garimpeiros
1937	Tepenquém (RR)	Diamond	Garimpeiros
1941	Serra do Navio (AP)	Manganese ore	Mário Cruz/Group CAEMI
1952	Rondônia (RO)	Cassiterite	Garimpeiros
1955	Médio Amazonas (AM,PA)	Rock Salt	PETROBRÁS
1955	Nova Olinda (1-NO-2-AM)(AM)	Oil-Gas	PETROBRÁS
1958	Médio Tapajos (PA)	Gold	Garimpeiros
1963	Tropas (Tapajos)(PA)	Cassiterite	Garimpeiros
1966	Sereno (PA)	Manganese ore	CODIM (Union Carbide)
1966	Trombetas (PA,AM)	Bauxite,Metallurgical	Group ALCAN
1967	Carajas (PA)	Iron ore	Meridional (USS)
1967	Buritirama (PA)	Manganese ore	Meridional (USS)
1968	Morro do Felipe (AP)	Kaolin	Jari (Group Ludwig)
1969	Maraconai (PA)	Titanium ore	CODIM (Union Carbide)
1969	Maicuru (PA)	Titanium ore	Meridional (USS)
1970	Velho Guilherme (PA)	Cassiterite	IDESP/PROMIX
1970	Mocambo (PA)	Cassiterite	PROMIX
1970	Paragominas (PA)	Bauxite,Metallurgical	Group RTZ
1970	Capim (PA)	Kaolin	CPRM/Mendes Júnior
1971	Azul (Carajas)(PA)	Manganese ore	AMZA (Group CVRD)
1971	Quatipuru (PA)	Chromite	DOCEGEO (Group CVRD)
1972	Jabuti (Paragominas)(PA)	Bauxite,Matallurgical	DOCEGEO (Group CVRD)
1972	Almeirim (PA)	Bauxite,Metallurgical	DOCEGEO (Group CVRD)
1973	Almeirim (PA)	Bauxite,Firebrick	DOCEGEO (Group CVRD)
1973	Onça-Puma (PA)	Niquel ore	Group INCO
1974	Itamaguari (PA)	Gipsum	CPRM
1974	Antônio Vicente (PA)	Cassiterite	DOCEGEO (Group CVRD)
1974	Vermelho (Carajas)(PA)	Niquel ore	AMZA (Group CVRD)
1974	Bahia (Carajas)(PA)	Copper ore	DOCEGEO (Group CVRD)
1974	NS (Carajas)(PA)	Bauxite,Metallurgical	AMZA (Group CVRD)
1975	Seis Lagos (AM)	Niobium ore	Projeto RADAMBRASIL (DNPM)
1975	Surucucus (RR)	Radioactive ore	Projeto RADAMBRASIL (DNPM)
1975	Surucucus (RR)	Cassiterite	Garimpeiros
1976	MM1 (Carajas)(PA)	Copper ore	AMZA (Group CVRD)
1976	Andorinhas (PA)	Gold	DOCEGEO (Group CVRD)
1976	Juruá (1-JR-1-AM)(AM)	Gas	PETROBRÁS
1976	Amapá (1-APS-10B)(AP)	Gas	PETROBRÁS
1976	Amapá (1-APS-21)(AP)	Oil-gas	PETROBRÁS
1977	Salobo (Carajas)(PA)	Copper ore	DOCEGEO (Group CVRD)
1979	Camoai (Paragominas)(PA)	Bauxite,Firebrick	DOCEGEO (Group CVRD)
1980	Pará (1-PAS-9)(PA)	Oil-Gas	PETROBRÁS
1980	Serra Pelada (PA)	Gold	Garimpeiros

Source: AMAZONIA by BRENO AUGUSTO DOS SANTOS, 1982

Generally speaking, mining activities in the Amazon Region are relatively active at present and IUM (Tax on Mineral Products) revenues from the mining industry showed an increase of 34.1% in 1982 over the previous year, while the increase ratio in 1981 was 27.7%. Processing activities also remain active and IPI (Tax on Industrial Products) from the processing industry operating in the Region has substantially increased.

In 1980, a new wolframite ore deposit was discovered in Sao Felix do Xingu and the production of wolframite in this new deposit reached 515 tons in two years. Production of columbite also recorded a substantial increase and gold production was increased by 57.8% in 1982 over the previous year, constituting 50% of the total value of mineral resources produced in the Region. This large increase is due mainly to the discovery of the Serra Pelada gold ore deposit. The Brazilian Government was planning to replace more than 20,000 "garimpeiro" working in these mines with modern machinery as of the end of 1983.

In 1982, the Pitinga ore deposit in the state of Amazonas, increased the Region's IUM revenue by 629.2%. The state of Para had the second highest IUM revenue in 1982 owing to increased bauxite export and the mining of wolframite in "garimpos (small or minor mines)," in addition to the mining of gold in Serra Pelada, Tapajos, Cumaru, Santarem and Itaituba.

Federal Territory of Amapa has the third largest IUM revenue owing mainly to the production of manganese ore at the Serra do Navio manganese ore deposit.

The amounts of principal mineral resources produced between 1978 and 1982 in the Region are shown in Table 2-12 which also includes mining-related data such as electricity and water consumption as well as amounts of IUM, IPI, investments and tax incentives.

Table 2-12 Basic Indices of Mining and Industrial Sector in the Northern Region (1978-82)

States of RONDONIA, ACRE, AMAZONAS, RORAIMA, PARÁ AMAPÁ, GOIÁS, MARANHÃO, MATO GROSSO

Mineral Production	Unit	1978	1979	1980	1981	1982
Mineral Water	Kl.	2,897	4,763	6,125	8,876	9,323
Clay	ton	46,800	80,868	170,864	80,467	152,442
Sand	ton	50,163	111,269	252,308	201,475	538,028
Gravel	ton	1,741	4,491	56,451	61,158	22,325
Stone	ton	7,341	11,079	26,075	47,267	33,343
Macadam	ton	2,407	7,560	33	4,540	89,558
Limestone	ton	484,728	580,859	519,828	618,613	867,342
Calcarious shell	ton	3,626	2,614	0	0	0
Kaolin	ton	74,420	116,072	178,846	121,110	206,813
Pyrophyllite	ton	15,006	8,918	614	14,044	22,256
Bauxite	ton	-	-	3,172,594	3,248,808	2,830,711
Manganese	ton	783,088	1,232,206	1,226,855	987,600	897,578
Columbite	ton	4	3	13	3	150
Cassiterite	ton	8,717	9,587	9,960	13,007	12,712
Wolframite	ton	-	-	-	459	515
Gold	Kg	1,359	950	10,290	11,283	17,806
Collection of IUM	Cr$million	3,096	3,806	4,647	3,362	4,507
Collection of IPI	Cr$million	32,150	29,532	28,457	17,882	36,047
Consumption of electric power	KWh	360,441	351,138	417,858	434,829	472,657
Consumption of cement	ton	520,342	635,257	791,230	984,933	1,230,525
Production of cement	ton	300,026	326,036	315,486	388,000	510,000
Licensed area for construction	m^2	638,613	1,077,695	852,048	813,416	974,231
Application of BNH	million m^2	10,448	22,693	27,624	26,453	40,373
Indices of average cost of construction						
Civil	Cr$/$m^2$	132.06	204.01	435.87	815.79	1,936.27
Generation of electric power	MWh	1,711,627	1,974,668	2,178,759	2,368,633	2,698,156
Consumption of electric power	MWh	1,349,300	1,558,188	1,753,300	1,916,848	2,143,315
Consumption of water	1,000 m^3	134,854	152,685	176,048	173,262	193,137
Value of approved projects						
Investments Total	Cr$million	83,124	36,831	30,971	85,777	46,824
Incentives of Tax	Cr$million	30,011	19,226	14,448	38,099	20,964

Source: AMAZONIA, INDICADORES CONJUNTURAIS, 1982

2-3 Mineral Resources in the Amazon Region

The most important mineral resources in the Amazon Region are iron, manganese, copper, nickel, tin, gold, diamond, potassium, rock-salt, aluminium, kaolin and natural gas.

Among other areas, the so-called Mineral Province of Carajas is considered to have the highest potential of mineral resources.

2-3-1 Mineral Province of Carajas

Mineral Province of Carajas is centered in the city of Maraba in the southern part of the state of Para and is located between two rivers, Araguaia-Tocantins river and Xingu river. Although underground resources in the Province are not entirely revealed, details of iron formations in the Province have come to be well known.

The principal iron ore deposit has been found in the mountain range of Serra dos Carajas which lies approximately 550 km to the south of the city of Belem and 780 km to the south-west of the city of Sao Luis. It is estimated that the deposit has a total of 18 billion tons of iron ore reserve (see Table 2-13). The deposit is ready to be mined by the open-pit method and the ores are ideal for sinter-feed processing whose products are in sharp demand in the world markets. Other deposits of iron ore of lesser quality are also found in and around the Province with an estimated total reserve of 20 billion tons, although no detailed survey has yet been carried out for these deposits.

As for manganese, a total of approximately 60 million tons of ore reserve is reported to exist in the manganese deposits of Buritirama (12 million tons of 46% Mn), Igarape Azul (45 million tons of 42.2% Mn), and Sereno (3 million tons of 40% Mn) in the Province. The manganese deposits of Buritirama and Sereno resemble those of Serra do Navio and Morro da Mina, while the Igarape Azul deposit, which is a heaped deposit, is considered the most important manganese ore deposit.

Bauxite ore deposits have also been found in the Province with an estimated total ore reserve of 45 million tons. These bauxite deposits are formed by the alteration of basic volcanic rocks into the country rocks of iron ore deposits in Serra dos Carajas.

Copper deposits in Serra dos Carajas constitute an important cupriferous belt. The Salobo copper deposit, of which a more detailed discussion is made in Chapter 4, is the most important copper deposit in Brazil with an estimated reserve of one billion tons of manganese ores (0.8 - 1.0% Cu and 0.4 g/ton Au).

Nickel ore deposits exist mainly in the southern part of Serra dos Carajas in which an estimated total reserve of 124 million tons of nickel ore (1.3 - 2.0% Ni) is reported to exist. The principal nickel deposit is located in Igarape Vermelho with an estimated total ore reserve of 45 million tons (1.5% Ni).

Cassiterite has been discovered in the Xingu-Iriri region and, in particular, in such areas as Antonio Vicente, Mocambo and Velho Guilherme. The cassiterite ore deposit in Antonio Vicente was discovered in 1974 and is considered one of the best deposits of cassiterite concentrate in Brazil. Estimated ore reserves at the Antonio Vicente and Mocamba deposits are 20,000 tons and 5,000 tons respectively.

Gold is another important mineral resource discovered in the Province. In Serra Pelada, a primary remobilized deposit of gold has been discovered and mined by "garimpeiro." Besides, primary mineralization of gold has been confirmed in the mountainous regions of Andorinhas and Gradaus.

Table 2-13 Mineral Potential in the Carajas Region

Mineral	Reserve/Potential million tons	Average Grade
Iron Ore	17,885	66.0% Fe
Manganese	60	43.0% Mn
Copper	1,000	0.9% Cu,0.48g/ton Au
Bauxite	45	46.0% Al_2O_3
Nickel	124	1.7% Ni
Cassiterite	0.1	67.0% Sn

2-3-2 Trombetas Region

Although bauxite was discovered in the Trombetas region in 1965, it was not until 1967 when the exploitation of bauxite in this region was found economically viable as a result of a regional survey which covered a total of 7,000 km^2 along the Amazon river and another 2,400 km^2 along the Trombetas river. According to the survey, the Trombetas region is expected to have deposits of kaolinite, copper, nickel, titanium and vanadium in addition to bauxite (49% Al_2O_3) whose estimated total reserve is 1.5 billion tons.

2-3-3 Paragominas Region

The Paragominas region covers the area to the south of the city of Belem, along the Gurupi river and across the states of Para and

Maranhao. In a survey conducted during the 70's, it was discovered that bauxite was widely distributed in the region. The so-called Paragominas bauxite belt with an estimated reserve of 2.4 billion tons of bauxite ore (49% Al_2O_3 and 4.5% SiO_2), covers an area as large as 65,000 km2, with a length of more than 410 km (S-N) and a width of approximately 230 km along the southern edge and that of 100 km along the northern edge of the bauxite belt.

In addition, the existence of kaolinite has also been confirmed in the areas along the Belem-Brasilia highway and along the Capim river between Paragominas and Sao Miguel do Capim, covering a total of 3,000 km2.

2-3-4 Tapajos Region

Gold in the Tapajos region was discovered more than 25 years ago and has been mined by "garimpeiros." The mineralized zone extends some 140,000 km2 along the Tapajos river and the major part of the zone consists of a folded series of volcanic sedimentary rocks, directly covering base crystalline rocks. In the western central part of the Region, a mineralized zone of cassiterite has also been discovered.

2-3-5 Technical Research Related to the Exploitation of Mineral Resources

The organization known as CETEC (Fundacao Centro Tecnologico de Minas Gerais) is one of the research organization responsible for the development of mining-related technology for the planned exploration of mineral resources in the Greater Carajas Program Area (the PGC Area). Other major research organizations include Centro de Pesquisas e Desenvolvimento (CEPED), Centro de Tecnologia Mineral (CETEM) and Instituto de Pesquisas Tecnologicas dc Estado de Sao Paulo (IPT).

During the period between 1972 and 1980, a total of US$174 million was spent on a number of research projects. In particular, the following researches in relation to the exploitation of four principal mineral resources in the PGC Area have been either planned or carried out:

(a) Aluminium

Studies of characteristics of bauxite ore mined at the deposits in Trombetas, Paragominas, Almeirim and Carajas have been carried out by DETEG/CVRD. According to Centro de Pesquisas do Aluminio, a total of US$0.6 million was invested by CVRD in the period during 1980 to 1982.

(b) Copper

Studies related to the floatation and leaching of sulfide and altered minerals mined in Serra dos Carajas are being undertaken by DETEG/CVRD, CEPED and CETEM. Application of pirometallurgy and hydrometallurgy are also being studied under the finance of FINEP and CVRD. The budget for the period between 1980 and 1986 is US$ 1.7 million.

(c) Iron

Studies of metallurgical disintegration and characteristics (reductivity, crepitation, porosity, etc.) of the Carajas iron ore as well as a research related to the development of a new reduction process are being undertaken by DETEG/CVRD at a budget of US$0.97 million for the period between 1980 and 1986.

(d) Manganese

Studies of characteristics and metallurgical tests for ferro-alloy fabrication of the Azul manganese ore have been carried out by DETEG/CVRD and CETEC at an annual budget of US$60,000.

2-3-6 Production Plans and Incentives

The mineral-metallurgy part of the Greater Carajas Program includes the development and production of mineral resources such as bauxite, alumina, aluminium, iron, manganese, copper, tin and gold. Although the success of the Program is in part dependent on foreign investments and imported technology, Brazilian Government has adopted several measures including fiscal and financial incentives to encourage investments by domestic private enterprises.

In particular, the Government adopted a special measure in 1979 in order to encourage private investments in the aluminium sector in the Amazon Region. The measure is consisted of the following incentives (Decision No.1654 of August 13, 1979, Ministry of Mining and Energy):

- Investors are guaranteed that the energy portion of the cost of aluminium production will not exceed 20% of international aluminium prices at any time for a period of 20 years.
- Provision of infrastructure by the Government for a project known as "Projeto ALBRAS/ALUNORTE." This will also benefit other projects being or to be carried out by private companies supported by domestic or foreign capital in Barcarena in the state of Para.
- Exemption from income tax for projects being or to be carried out in the Amazon Region for a period of 10 - 15 years. This tax exemption is also applied to those projects that are not necessarily related to the production of aluminium.

According to the concerned government institutions, production/investment plans have been proposed as follows:

(a) Copper

A copper deposit referred to as "Salobo 3-A" was discovered in 1976 and the launching of an industrial mining operation at the deposit is expected in 1988. Geological and technological surveys and a feasibility study are being carried out at an estimated investment of US$100 million for the period between 1981 and 1985. As a preliminary plan, production of one million tons/year of copper concentrate (32% Cu), 160 million tons/year of copper metal, 470,000 tons/year of sulfuric acid and 500 kg/year of gold is considered at a total investment of US$1.6 billion. Part of the copper concentrate produced at the Salobo 3-A deposit will be supplied to the domestic market (Caraiba Metais).

(b) Aluminium

A geological survey related to bauxite in the PGC Area has been carried out; however, it would take several more years to complete a feasibility study and basic research. As a preliminary plan, mining of 1.44 million tons/year of bauxite and production of 480,000 tons/year of alumina and 240,000 tons/year of aluminium are considered. "Projeto ALBRAS/ALUNORTE" aims to expand the smelter complex in Barcarena to double the production of alumina and aluminium to 800,000 tons/year and 320,000 tons/year respectively by 1990's at an estimated total investment of US$2,960 million.

(c) Nickel

Production of 20,000 tons/year of nickel content (ferro-nickel) from a total of 1.66 million tons/year of crude ore is planned at an investment of US$470 million. The plan, however, will be put into effect after 1986, since a concurrent survey of nickel ore deposits has been delayed.

(d) Manganese

Production of 150,000 tons/year of ferro alloy from a total of 500,000 tons/year of crude manganese ore is being planned. Although the exploration of the major manganese ore deposit in Azul has already been completed, a few more years are required to complete basic engineering studies.

(e) Tin

Production of 2,000 tons/year of Sn concentrate in and around the Sao Felix do Xingu district is being planned.

(f) Metallic Silicon

Production of 30,000 tons/year of metallic silicon is being planned.

Table 2-14 lists major projects by Federal Government in the PGC Area, indicating locations of the projects, capital component ratios, investments and other important data. Table 2-15 shows a chronological breakdown of investments in each sub-program from 1981 to the year 2000. Figure 2-16 shows investments, production plans and other data related to the mining and metallurgical projects in the PGC Area.

Table 2-14 Major Projects by Federal Government in Eastern Amazon

Program - Project	Location	Capital							Leading Company	VBP annual (US$ million)	Production	
		Nat. Private		Governmental		Transnational		Total			(%)	(%)
		US$ million	%	US$ million	%	US$ million	%	US$ million			Domestic	Export
1. Carajas Program Area												
A. Segm. Mine-Metallurgy	S. Norte	2,318	25	93	1	6,860	74	9,270	Trans-nat.	7,605	15	85
B. Segm. Agroflorest	S. Norte	660	30	0	0	1,540	70	2,200	Trans-nat.	7,770	35	65
C. Infra structure	S. Norte	0	0	2,550	100	0	0	2,550	Trans-nat.	750	25	75
2. Carajas Iron Project	S. Norte	0	0	1,510	100	0	0	1,510	National	770	0	100
3. Albrás - Alunorte	PA	0	0	390	50	390	50	780	Trans-nat.	610	0	100
4. Alcoa	MA	0	0	0	0	1,200	100	1,200	Trans-nat.	960	20	80
5. Tucurui	PA	0	0	700	100	0	0	700	National	750	100	0

Program - Project	Construction (year)		Investment US$ million		Import US$ million		Finance US$ million		Partic of World Bank	Technology		Labor US$ million	
	Start	Fin.	Without Interest	with Interest	Direct	Indirect	National	Intern.		(%) National	(%) Imp.	Direct	Indirect
1. Carajas Program Area													
A. Segm. Mine-Metallurgy	1982	1987	22,550	29,390	6,300	11,100	4,560	8,790	Y	26	74	138	276
B. Segm. Agroflorest	1982	1987	11,093	12,893	1,800	3,500	2,670	6,230	Y	40	60	300	600
C. Infra structure	1982	1987	22,500	40,500	2,500	7,000	6,000	14,000	Y	100	0	70	175
2. Carajas Iron Project	1980	1987	3,800	4,300	500	900	1,060	1,230	Y	100	0	6	30
3. Albrás - Alunorte	1978	1986	2,600	3,530	900	1,700	910	910	N	0	100	-	-
4. Alcoa	1980	1984	2,980	3,880	1,800	220	180	1,600	N	0	100	-	-
5. Tucurui	1976	1983	3,700	5,600	2,000	2,500	1,200	1,800	N	60	40	3	15

Source: CARAJAS, IBASE, 1983

Table 2-15 Chronogram of Investments, Carajas Mineral Province

(Unit: US$million)

	1981/82	1983/84	1985/86	1987/88	1989/90	1991/92	1993/94	1995/96	1997/98	1999/2000	Total
I. Segment Mining - Metallurgy of Carajás											
Fe											
Carajas Iron Project	(1,259)*	(1,000)*	(845)*								3,104
Cu											
Prospection, etc.	30	40	30	-	-	-	-	-	-	-	100
Mine	-	-	300	500	150	-	-	-	-	-	950
Smelter	-	-	150	300	100	-	-	-	-	-	550
Sub Total	30	40	480	800	250	-	-	-	-	-	1,600
Bauxite/Aluminium											
Survey etc.	-	50	-	-	-	-	-	-	-	-	50
Mine	-	-	20	-	-	-	-	-	-	-	20
Alumina Plant	-	-	200	100	-	-	240	250	-	-	790
Aluminium Plant	-	-	480	360	-	-	500	760	-	-	2,100
Sub Total	-	50	700	460	-	-	740	1,010	-	-	2,960
Nickel											
Survey etc.	5	10	5	-	-	-	-	-	-	-	20
Mine/Plant	-	-	150	300	-	-	-	-	-	-	450
Sub Total	5	10	155	300	-	-	-	-	-	-	470
Manganese											
Survey etc.	5	5	-	-	-	-	-	-	-	-	10
Mine/Plant	-	50	100	-	-	-	-	-	-	-	150
Sub Total	5	55	100	-	-	-	-	-	-	-	160
Tin & Metallic Silicon	-	10	-	-	-	-	50	-	-	-	60
Infra structure	200	400	400	300	200	200	400	500	500	500	3,600
Total I	1,499	1,565	2,680	1,860	450	200	1,190	1,510	500	500	11,954
			8,054					3,900			11,954
II. Segment Iron & Steel											
Cast iron AF	-	-	90	90	90	90	-	-	-	-	360
Expansion	-	-	-	-	-	-	90	90	90	-	270
Sinter	-	-	-	-	-	130	130	-	-	-	260
Cast iron BFER & Sponge	-	-	-	-	-	-	-	400	700	800	1,900
Semi-products of steel	-	-	-	-	-	-	400	800	2,000	800	4,000
Coke	-	-	-	-	-	-	40	80	200	80	400
Survey & Technology	10	20	20	30	30	30	30	50	50	50	320
Total II	10	20	110	120	120	250	690	1,420	3,040	1,730	7,510
			380					7,130			7,510
III. Segment Renewal of Forest	10	25	25	25	25	25	276	276	276	276	1,239
IV. Segment Agriculture	15	70	40	70	120	220	220	230	430	430	1,845
V. Segment Stock farming	2	5	5	5	5	10	10	10	10	10	72
VI. Infra structure for Agriculture and forest	50	100	150	250	350	400	500	600	700	800	3,900
VII. Navigability of Tocantins & Araguaia	100	100	100	150	150	200	300	400	400	400	2,300
Grand Total	1,686	1,885	3,110	2,480	1,220	1,305	3,186	4,446	5,356	4,146	28,820
			10,381					18,439			28,820

Source: CARAJÁS, IBASE, 1983
* : Estimated by the Study Team

Table 2-16 Investment Program in the Greater Carajas Program Area (1980-1990)

	Project/Company	Location	Type of Project	Investment US$ million-1981		Production thousand t/Y		Market	Period	Start of Production	Remarks
				Total	Invested	Present	Plan				
Al	ALBRAS (CVRD/NAAC)	Barcarena-PA	Metallurgy	1,517	172		Al 320	Export	1980-89	1985/90	Alumina is supplied by ALUNORTE
	ALCOA	Oriximina-PA	Mining	56	-		Bauxite 4,000	Domestic Export	1980-	-	
	ALUMAR (ALCOA/SHELL)	São Luis-MA	Metallurgy	1,085	86		Alumina 500 Al 100	Domestic Export	1980-84	1984	
	ALUMAR	São Luis-MA	Metallurgy	659	-		Al 300	Domestic Export		1989	Plant expansion
	CPA (VOTORANTIM)	São Luis-PA	Metallurgy	536			Al 160	Domestic Export	1980-	-	
	DOCEGEO (CVRD)	Almeirim-PA	Metallurgy	63			Alumina 100	Domestic Export	1980-	-	
	MRN (CVRD/CBA)	Oriximina-PA	Mining	200	5.8	3,288	6,700	Domestic Export	1982-86	1986	
Cu	CARAJAS/CVRD	Marabá-PA	Mining Metallurgy	1,500	17.2	-	1,000	Domestic	1980-86	-	160,000 t/Y Cu, 470,000 t/Y H2SO4, 6.5 t/Y Au
Fe	CARAJAS/CVRD	Marabá-PA	Mining	3,636	619	-	35,000	Export	1980-	1985	Expansion program up to 50 millions t/Y
Kaol.	Caulim da Amazonia Ltd. (ANTUNES)	Almeirim-PA	Mining	51	33	193	303	Domestic Export	1985-86	1986	
	Caulim da Pará S.A. (MENDES JUNIOR)	São Domingos de Capim-PA	Mining	45	2	-	208	Domestic Export	1982-84	1984	
Mn	Manganese Carajas	Marabá-PA	Mining	30	1.5	-	825	Domestic	1983-86	1986	45% Mn
Sn	MOCAMBO/PPOMIX	São Felix do Xingu-PA	Mining	5.4	0.4	-	1.2	Domestic	1981-83	1983	65% Sn

Source: INVESTIMENTOS-1982, DNPM, CONSIDER

3. Review and Analysis of Past and Current Exploration Projects

As noted in the beginning, the Study Team has collected a number of study reports as well as uncompiled data related to the exploration and development of mineral resources in the PGC Area. In this chapter, the major thrusts of these reports and data will be briefly reviewed and discussed in three categories: geological, geochemical and geophysical.

3-1 Geological Survey

National Department of Mineral Production (DNPM) listed 84 reports of geological surveys carried out by Brazilian organizations, of which 42 reports were selected for the current study. These survey reports have been classified into the following three groups on the basis of scales of geological maps prepared in the surveys:

- Group 1: Those at scales over 1:250,000 (mainly 1:1,000,000)......................19 projects
- Group 2: Those at scales of 1:250,000 - 1:100,000...16 projects
- Group 3: Those at scales below 1:100,000............ 7 projects

Plate III-1 shows locations and areas in which these projects were carried out and Appendix 1 presents summaries of the projects.

Group 1

Exploration projects classified in this group mainly consist of regional exploration projects by DNPM/CPRM. Geological maps of the areas covered in these surveys are found in the report, "Projeto RADAM BRASIL (Vol.1 - 5 and 22)" of DNPM (1974 and 1975). For the compilation of a geological map at a scale of 1:1,000,000 in the Phase II Study, the maps included in the following seven reports have been used:

(a) DNPM/CPRM (1978): "Projeto Estudo Global dos Recursos Minerais Bacia Sedimentar do Paranaiba"

(b) DNPM/CPRM (1979): "Projeto Integracao Geologico-Geofisica Sul do Para"

(c) DNPM (1981): "Projeto RADAMBRASIL (Vol.22)"

(d) DNPM (1974): "Projeto RADAMBRASIL (Vol.4)"

(e) DOCEGEO (1982): "Geologia Regional da Provincia Mineral de Carajas"

(f) CPRM (1982): "Esboco Geologico da Folha Araguaia"

(g) DNPM (1981): "Mapa Geologico do Brasil"

Group 2

All the 16 projects classified in this group aimed at exploring mineral resources in selected areas including Serra dos Carajas, Serra das Andorinhas and Serra dos Gradaus (Cumaru). IDESP and PETROBRAS also undertook surveys related to the exploration of non-metallic ore and petroleum respectively in the PGC Area.

Group 3

The seven projects classified in this group have been carried out by CVRD, DNPM/CPRM, and DNPM/UFPa (Federal University of Para) aiming specifically at the discovery of metallic ore deposits in the PGC Area. As such, these exploration projects were carried out at a comparatively small scale and covered only limited areas.

The principal objective of these projects was the identification of ore deposits and the evaluation of mineral potential of these deposits on the basis of the results of regional geological, geochemical and geophysical surveys. As such, these projects consisted mainly of the examination and analysis of known data as well as the interpretation of radar images and aerophotography. As for field checking surveys, they have often been carried out quite roughly, although CVRD/DOCEGEO have conducted a detailed survey in and around the mountain range of Serra dos Carajas.

In reviewing these 42 reports, several problems in respect to stratigraphic correlation and classification have been identified as follow:

(1) Succession of Xingu Complex - Grao Para Group

DNPM/CPRM describes that the basement of the so-called "Xingu Complex" mainly consists of crystalline rocks and is overlain by a geologic unit known as "Grao Para Group" as defined by CVRD/Meridional (1972), consisting of basic volcanic rocks and metamorphic rocks. According to CVRD/DOCEGEO, a "greenstone belt" consisting of metabasite of a low metamorphic grade is intercalated within the Xingu Complex. Further, the Salobo-Pojuca sequence, which embeds copper deposits, is said to be divided independently from the lower part of the Grao Para Group. CVRD/DOCEGEO also states that the Grao Para Group lies on the Salobo-Pojuca sequence and is stratigraphically correlated to iron formation. Their statigraphic classification of the geology of Serra dos Carajas, however, is not necessarily in agreement with the known regional geological order. In addition, their explanation of the formation and characteristic of the "greenstone belt" differs from one report to another. One explanation is that the greenstone belt is interbedded within the Xingu Complex. The other explanation states that it is a stratum consisting of metabasic rocks, meta-ultrabasic rocks and metavolcanic sediment including the Grao Para Group, overlaying the Xingu Complex. In view of the known geology of the subject area, however, the latter explanation seems appropriate.

(2) Stratigraphical Location of Tocantins Group and Estrondo Group

The relationship between the above two groups and Precambrian basement rocks has been generally explained as that of tectonic unconformity. Many reports, however, have presented different explanations and no unifying theory has yet been proposed.

"Projeto RADAMBRASIL (Vol.22: 1981)" and Almeida and Hasui (1980) presented the following geochronological classification:

>2,000 m.y.	-	Archean
1,400 m.y.	-	Uruacuan Cycle
650 m.y.	-	Brazilian Cycle

As to the period of Uruacuan Cycle, the geologic age has been obtained from samples of crystalline rocks outcropping as windows in the vicinity of Araguaia river. As for the period of 650 m.y., it is assumed to indicate the juvenescent period affected by metamorphism of the Brazilian Cycle.

According to Almeida and Hasui (1980) and Amaral (1974), Tocantins Group and Estrondo Group had been formed in the Pre-Brazilian Cycle. Our study adopted their interpretaion.

(3) Distribution of Rio Fresco Formation and Grao Para Group and their Stratigraphical Relationship

Rio Fresco Formation is distributed in the mountain ranges of Serra dos Carajas, Serra dos Gradaus and Serra das Andorinhas. Stratigraphically, Rio Fresco Formation has been generally considered unconformable with the Grao Para Group. However, a further study is required to determine their stratigraphical relationship since geological maps drawn at scales of 1:2,500,000 and 1:1,000,000 (DOCEGEO) and the results of Landsat image analysis indicate a conformable distribution of the Rio Fresco Formation with the Grao Para Group.

3-2 Geochemical Survey

A total of 16 geochemical projects related to the exploration of mineral resources in and around the PGC Area have been carried out up to the present and 13 projects as mentioned below have been selected for analysis. Plate III-3 shows locations in which these projects were carried out and Appendix 2 presents summaries of the 13 projects.

The geochemical exploration projects have been grouped into the following two categories according to their scopes and objectives:

- Regional Surveys:

  The principal objective is to find areas in which the probability of the existence of a mineral resource or resources is very high. A regional survey usually covers an extraordinarily broad area.

- Detailed Surveys:

  The principal objective is to discover ore deposits in the areas selected in regional surveys. As such, they cover relatively small areas and include detailed studies as to the scale and characteristics of a particular ore deposit.

In view of the purpose of the Phase II Study, existing survey reports in the former category have been reviewed to synthesize the findings described in these reports. In this process, anomalous value distribution maps (see Plate III-4 and -5) have been compiled at a scale of 1:1,000,000 which is the same scale as that of the geological map mentioned in Section 3-1. A careful review and analysis of existing survey reports in the latter category has also been undertaken with particular emphasis on such elements as gold (Au), copper (Cu), tin (Sn), nickel (Ni), cobalt (Co) and manganese (Mn).

(1) Regional Geochemical Exploration

While eight geochemical projects of a regional scale have been carried out up to the present, the following seven reports in 14 volumes have been reviewed in detail:

(a) DNPM/CPRM (1975): "Projeto Gurupi, Relatorio Final de Etapa (Vol. I, II and III)"

(b) DNPM/CPRM (1977): "Projeto Gurupi, Relatorio, Etapa II (Vol. I, II and III)"

(c) DNPM/CPRM (1974): "Projeto Norte da Amazonia, Reconhecimento Geoquimico (Vol. VI-A)"

(d) DNPM/GSC: "Projeto Geofisico Brasil-Canada (Vol. VI and VII)"

(e) DNPM/CPRM (1972): "Projeto Maraba, Geoquimica (Vol. XI)"

(f) DNPM/CPRM (1980): "Projeto Rio Chiche, Relatorio de Progresso (Vol. I)"

(g) SUDAM/CPRM (1975): "Projeto Xingu-Araguaia (Vol. I, II and III)"

As shown in the above, five out of the seven projects were undertaken jointly by DNPM and Mineral Resources Exploration Co. (CPRM). The other two projects were also carried out by DNPM and CPRM with Geological Survey of Canada (GSC) and the Superintendency for the Development of Amazonia (SUDAM) as their respective partners. These regional survey projects have been undertaken in the northwestern, northeastern and southwestern parts of the PGC Area, which are geologically dominated by Precambrian basic rocks. The project referred to as "Projeto Gurupi" was undertaken in what is called "Sao Luis Craton" in the northwestern part of the PGC Area, while the other four projects were related to the southwestern part covering the mountain range of Serra dos Carajas.

In reviewing the above reports, many flaws in respect to survey methods and report compilation were found. As for the reports of Projeto Gurupi, Projeto Maraba and Projeto Rio Chiche, it was found that samples had been collected only from the mainstream of large rivers and that effective samples had been barely collected. In Projeto Norte da Amazonia, samples taken in the survey area were found insufficient to compile a geochemical anomaly map for the northwestern part of the PGC Area which was supposed be covered by this project. As for Projeto Xingu-Araguaia, the Study Team was not able to obtain a complete set of the report and, therefore, an anomaly distribution map covering the Xingu-Araguaia area cannot be compiled.

Consequently, anomalous value distribution maps have been compiled only for two areas covering the northeastern and southwestern parts of the PGC Area as shown in Plate III-4 and -5. In compiling the anomaly distribution maps, all the related date included in respective reports have been carefully examined; however, only those samples representing areas of approximately 25 km2 have been considered effective. The drainage maps drawn at a scale of 1:250,000 have been instrumental in compiling the anomaly maps.

(2) Detailed Geochemical Exploration

While eight detailed survey projects have been carried out up to the present, the following six reports were selected for analysis:

(a) DNPM/PROSPEC S.A. (1970): "Projeto do Cobre-Para, Relatorio Final, Etapa II"

(b) DOCEGEO (1978): "Relatorio Final de Pesquisa, Area Antonio Vicente (Vol. I)"

(c) DOCEGEO (1981): "Projeto Cobre-Carajas, Jazidas Salobo 3A e 4A"

(d) DNPM/UFPa (1981): "Projeto Serra das Andorinhas, Relatorio Final"

(e) DNPM/CPRM (1977): "Projeto Sao Felix do Xingu, Relatorio Final (Vol. I)"

(f) DOCEGEO (1976): "Relatorio Final de Pesquisa, Serra do Quatipuru (Vol. I)"

In reviewing all the six reports, it was found that the detailed geochemical surveys took place in those areas where basic rocks are widely distributed and mineralization is recognized and where anomalous zones had been discovered in the regional surveys. In general, the number of exploration projects by private organizations such as DOCEGEO have been gradually increasing in recent years and such "private" projects often aim at discovering a particular mineral resource. For instance, Project do Cobre-Para and Projeto Cobre-Carajas were specifically aimed at discovering copper ore deposits and the target mineral resource of Projeto Sao Felix do Xingu was tin.

(3) Interpretation of Anomaly Distribution Maps

In the northeastern part of the PGC Area, anomalous values are concentrated in Sao Luis Craton and anomalies of gold (Au), cobalt (Co), nickel (Ni) and tin (Sn) are distributed in particular association with Sao Luis Craton. Au occurs in association with Gurupi Formation, while Sn is related to granitoide. Anomalies of copper (Cu) and manganese (Mn) are distributed not only in Sao Luis Craton but also in the upper strata.

In the southwestern part of the PGC Area, anomalies are concentrated in roughly three areas: the north, over the center to the south, and over the south to the west. The northern anomalies are located in the eastern part of Serra dos Carajas, corresponding to the distribution of the Grao Para Group and the Rio Fresco Formation. The succession of anomalies distributed in the direction of north-south over the center to the south, corresponds to the distribution of "Faixa Araguaia" of Tocantins Formation and Araguaia Group. This phenomenon seems to reflect the intrusion of the ultrabasic rocks. The anomalies distributed over the south to the west in the Inaja area almost correspond to the distribution of the Grao Para Group in which ultrabasic rocks dominate. In particular, anomalies of Cu, Ni and Co are predominant.

The "Projeto Rio Chiche" report (DNPM/CPRM: 1980) states that Au and Sn anomalies are distributed in the west, suggesting the existence of Au and Sn ore deposits. The report also indicates that the probability of the existence of Cu, Ni and Co ore deposits in the Inaja area is considerably high in view of the fact that the geology of the Inaja area is similar to that of the west.

In due consideration of the above data, it is considered most productive to carry out a regional exploration project aiming specifically at finding Cu, Au, Sn and Mn ore deposits in the following three areas:

- The area between Serra dos Carajas and Inaja
- The northwestern part of Serra dos Carajas including the Bacaja area
- The Inaja area including its western vicinity

The proposed regional exploration project as well as geological characteristics and mineral potentials of the above three areas will be discussed in detail in Chapter 5 of this study report, following a more detailed discussion of the geology of the PGC Area in Chapter 4.

3-3 Geophysical Survey

Twenty-three pieces of material covering 18 geophysical exploration projects carried out in and around the PGC Area were collected by the Study Team at DNPM's Headquarter and its branch office in Belem. Plate III-6 shows areas covered by the 18 projects and their outlines are presented in Table 3-1. The geophysical projects have been classified into several groups on the basis of exploration methods, organizations and types of exploration, and site locations as follows:

(a) Geophysical Exploration Methods

i) Aerial geophysical exploration

Magnetics	8 projects
Radiometrics	3 projects
Electro-magnetics (Input)	2 projects

ii) Ground geophysical exploration

Magnetics	5 projects
Electrical (IP)	3 projects
Electrical (SP)	1 project
Electrical (Schlumberger)	1 project
Electromagnetics (AFMT, VLF)	2 projects
Electromagnetics (Pulse EM)	2 projects
Radiometrics	8 projects

(b) Organizations and Types of Exploration

DNPM:	Metallic ore deposit survey Geological structural survey	3 projects
DNPM/NUCLEBRAS:	Metallic ore deposit survey Uranium ore deposit survey	1 project
CNEN/NUCLEBRAS:	Uranium ore deposit survey	3 projects
CNP/PETROBRAS:	Petroleum exploration	1 project
IRN/SUDENE:	Natural resources survey	1 project
IDESP/SUDAM:	Groundwater resources survey	1 project
CVRD/DOCEGEO:	Metallic ore deposit survey	6 projects

(c) Site Locations

i) Northern part of the PGC Area

Four projects related to petroleum, groundwater and geologic mapping have been carried out along the Atlantic coast.

ii) Eastern part of the PGC Area

Three surveys related to natural resources and geologic mapping have been carried out.

iii) Southwestern part of the PGC Area

Nine projects including metallic ore deposit surveys by DNPM/DOCEGEO and uranium ore deposit surveys by CNEN/NUCLEBRAS have been carried out. Minor projects have been excluded in our study.

Of the 18 geophysical projects, those carried out by PETROBRAS and IDESP/SUDAM are related to petroleum and groundwater and, therefore, have been excluded from our study. CNEN and NUCLEBRAS were mainly concerned with uranium and, therefore, other mineral elements were not covered in their surveys, although results of their radioactive exploration have been instrumental to our study. DNPM did not compile anomaly maps in their projects related to geological mapping. In addition, no detailed data are available as to the six metallic ore deposit surveys carried out by DOCEGEO. Consequently, the following two projects carried out in the southwestern part of the PGC Area have been studied in detail for the compilation of geophysical data:

Projeto Geofisico Brasil-Canada (PGBC):

This project was carried out by DNPM/GSC (Geological Survey of Canada) using airborne magnetic and radiometric survey methods. Maps produced in the project are aeromagnetic maps (1:250,000 and 1:750,000) and radiometric anomaly maps for uranium (Ur), thorium (Th) and for all elements included (Total) at a scale of 1:750,000.

Projeto Sul do Para:

This project was carried out by DNPM/NUCLEBRAS using airborne magnetic and radiometric survey methods. Maps compiled in the project include an aeromagnetic map at a scale of 1:250,000.

As for the maps compiled in Projeto Sul do Para, image resolution is very poor and the radiometric anomaly map only covers "Total" anomaly. Therefore, the maps compiled in Projeto Geofisico Brasil-Canada have been adopted as the base data from which new aeromagnetic maps as well as radiometric anomaly maps (Ur, Th and Total) covering the area north of latitude 10° south and east of longitude 53° west are drawn at a scale of 1:250,000.

(1) Qualitative Analysis

In examining the distribution of three types of anomaly (Ur, Th and Total) as appeared on the newly compiled radiometric maps, it was found that the "Th" component seems to reflect the distribution of acidic rocks such as granitic rocks and the boundaries of geological strata. A brief summary of the qualitative analysis of the "Th" anomaly map is given below, following a qualitative analysis of the new aeromagnetic maps (Also refer to Plate III-11, Interpretation Map).

(a) Aeromagnetic Maps

The area covered by the new aeromagnetic maps can be classified into three sub-areas (Areas A, B and C) on the basis of patterns of anomaly distribution.

"Area A" lies in the west of longitude 49° west. Magnetic anomalies of large amplitude are found in this area. In the north of latitude $6^\circ 30'$ south, over Serra dos Carajas to Bacaja, magnetic anomalies are distributed in the direction of WNW-ESE. Traverse anomalies are also found there. While the amplitude of magnetic anomaly is comparatively small in the central part of Area A, roughly between Serra da Seringa and Serra dos Andorinhas, magnetic anomalies are distributed in the east-west direction in Serra da Inaja and the south of Serra dos Gradaus.

"Area B" lies in the eastern part of Area A, divided by Araguaia river in the center. The variation of contour lines (equi-gamma lines) is poor and small magnetic anomalies are numerously scattered in the north-south direction. These magnetic anomalies seem to reflect the distribution of ultrabasic rocks which intrude in the same direction. It seems that sediment rocks are predominant in Area B.

"Area C" lies in the eastern part of the PGC Area, stretching from north to south with magnetic anomalies of comparatively small amplitude.

The patterns of magnetic anomaly distribution are quite different in the above three areas and the existence of magnetic discontinuity lines at the boundaries of the three areas can be assumed. While the magnetic discontinuity line "D1" (see Plate III-11, Interpretation Map) between Areas A and B is presumably a geotectonic line, the discontinuity line "D2" between Areas B and C is considered to correspond to a geologic boundary. In addition, the existence of an obvious magnetic discontinuity line "D3" streching in the direction of ENE-WSW in the north of Serra dos Carajas is assumed.

From the viewpoint of the exploration of metallic ore deposits, Area B, in which numerous dykes of ultrabasic rocks intrude, appears quite interesting since it is considered to have an intimate geological relationship with (1) nickel ore deposits, (2) the area from the center to the south in Area A, where granite associated with gold and tin ore deposits are found, and (3) the area to the north of Area A, where the Grao Para Group embeds Carajas-type iron, copper and manganese ores.

In the vicinity of Serra dos Carajas, basic-ultrabasic rocks of the Grao Para Group are distributed in the direction of WNW-ESE, showing a tendency to continue to the northwestern side of the geotectonic line "D3." In view of the fact that this tendency continues to Altamira, the existence of basic-ultrabasic rocks of the Grao Para Group is also assumed in the Bacaja area. Basic rocks are shown in terms of small scale magnetic anomalies in the center of Area A (Serra dos Carajas - Serra dos Andorinhas). This suggests that basic rocks form similar dykes in the area.

On the other hand, in the area over Serra dos Gradaus to Serra da Inaja in the south of Area A, outcrops of basic-ultrabasic rocks correspond to the distribution of magnetic anomalies. However, magnetic anomalies of large amplitude were also found in the western part of Conceicao do Araguaia. They have presumably been induced by the ultrabasic rocks whose top is assumed to exist in a shallower part. Although they do not appear on the geologic maps, they nevertheless remain interesting.

(b) Radiometric Anomaly Map (Th)

Radioactive discontinuity lines caused by the tendency of the anomaly directions of N-S and NNE-SSW have been assumed to exist mainly over the center to the east. These discontinuity lines correspond to geotectonic lines and to the boundaries of geological strata and rocks.

Interesting radioactive anomalies have been detected in the area between Serra dos Carajas and Serra do Inaja in the western area. These anomalies have presumably been induced by granite, while psammitic rocks in the Rio Fresco Formation are also assumed to have been the origin.

Surrounding these areas of anomalies related to granite and psammitic rocks, comparatively small yet intense anomalies have also been detected. While these anomalies detected in the subject area are all counted as granite of the same sort on the geological maps, they can be interpreted as younger granite whose geologic age is totally different from that of the granite occuring at a large scale. This remains interesting and the anomalies widely distributed from Serra dos Carajas to Serra da Inaja are considered extraordinally valuable.

(c) Summary of Qualitative Interpretation

i) Basic-ultrabasic rocks of the Grao Para Group embedding principal Carajas-type ore deposits, are found in the vicinity of Serra dos Carajas, extending toward the northwest. In addition, there is the possibility of the existence of the Grao Para Group in and around the Bacaja area.

ii) The large scale magnetic anomalies in the western part of Cenceicao do Araguaia are caused by the ultrabasic rocks whose tops are at a shallow part and could be confirmed by surface investigation.

iii) The dykes of basic-ultrabasic rocks are numerously distributed over the center to the west in the surveyed area.

iv) The radioactive anomalies detected in the area over Serra dos Carajas to Serra da Inaja are assumed to be caused by granite and psammitic rocks of the Rio Fresco Formation.

v) The radioactive anomalies as shown on the anomaly map are divided into two types of anomaly group: one that occurs at small amplitude and the other at large amplitude. The former corresponds to older granite distributed over a wide area and the latter corresponds to younger granite distributed at a comparatively small scale.

Table 3-1 Outline of Collected References

No.	Organization Executed	Year	Survey Period	Title of Project and/or Report	Air/Ground	Method *3	Purpose *4	Pos *5
P-1 *1	DNPM(/GSC)	1979	1975 - 1981	Relatório de encerramento das Atividades do PGBC -Projeto Geofísico Brasil- Canadá	Air	MAG,RAD,EM	TR, METAL	×
2 *1	DNPM(/GSC)	1981	1975 - 1981	Relatório Final Projeto Geofisico Brasil - Canadá	Ground	EM(CEM)		×
3 *1	DNPM (Northway Survey Co. Ltd.)	1982	1975 - 1981	Report to the DNPM, MME, Brazil on the General Magnetic and Radiometric Survey of the Projeto Geofisico Brasil - Canadá	Air	MAG,RAD	TR, METAL	○
4 *2	DNPM/NUCLEBRAS	1976	1974.9-1976	Relatório Final - Texto Projeto Sul do Pará 1 Parte Levantamento Aerogeofisico Magneto-Metria e Gamaespectrometria	Air	MAG,RAD	METAL, UR	○
5 *2	DNPM	1979	1978 - 1979	Projeto Integração Geologico-Geofisica Sul do Pará Relatório Final Volume I	Air	MAG,RAD	METAL	○
6	DNPM	1977	1975.8-1976.9	Projeto Sulfetos de Altamira-Itaituba Relatório Final Volume I	Ground	RAD	METAL	×
7	DNPM	1977	1971.4-1977.7	Projeto Gurupí Relatório Final de etapa Texto Volume I	Ground	RAD	GEOL	×
8	CNEN/NUCLEBRAS	1970	1968.11-1969.5	Projeto Tocantínia - Itacajá	Air	RAD	UR	×
9	CNEN	1971	1971.5.23 - 1971.7.2.	Projeto Balsas Reconhecimento Geológico - Radiométrico Preliminar	Ground	RAD	UR	×
10	CNEN	1971	1971.5.20 - 1971.7.25	Projeto Itapecuru Reconhecimento Geológico - Radiométrico Preliminar	Ground	RAD	UR	×
11	PETROBRAS	1970	1969.2-1969.9	Região do Barreirinhas Levantamento Aeromagnetométrico	Air (off-shore)	MAG	PET	×
12	IRN/SUDENE		1973.8 - ?	Projeto Maranhão	Air	MAG	NR(+1)	×
13	IDESP/SUDAM	1974	1971 - 1973	Estudos Integrados da Ilha de Marajó	Ground	EL(SCH)	WAT	×
14	SUDAM/CPRM	1975	1974.10 - 1974.12	Projeto Xingu-Araguaia Geologia e Geoquímica da Área Gradaús Nova Olinda Volume I	Air Ground	MAG RAD	METAL	×
15	[illegible]	[illegible]	[illegible]	Relatório de Pesquisa de Minério de [illegible]	Air	MAG	METAL	[illegible]

No.	Organization Executed	Year	Survey Period	Title of Project and/or its Report	Air/Ground	Method	Purpose	Pos
P-16	DOCEGEO	1976	1975.10 - 1976.11	Relatório Final de Pesquísa Serra do Quitapuru	Ground	MAG,EM,EL(IP)	METAL	△
17	DOCEGEO	1977	Air:1975.12.3 - 1975.12.12	Relatório Final de Pesquísa Serra das Andorinhas	Air Ground	MAG,EM(INP) MAG,RAD,EM (CEM,VLF)	METAL	△
18	DOCEGEO	1978		Relatório Final de Pesquísa Área Antonio Vicente Volume I Texto	Air	REI	METAL	△
19	DOCEGEO	1979	Air: 1974 Ground: 1977	Relatório de Pesquísa Projeto Cobre Carajás - Jazidas Salobo 3A e 4A	Air Ground	MAG MAG,RAD,EL(IP)	METAL	△
20	DOCEGEO	1984	1977.10-1984	Relatório de Pesquísa 1984 Projeto Cobre Pojuca	Ground	MAG,RAD,EL (IP,SP,MM), EM(AFMAG)	METAL	△
21 *1	Silva, R.W.S. and Sá, J.H. das.	1982		Feições geologicas e magnetométricas da região do Baixo Araguaia. Anais do I Simpósio de Geologia da Amazonia, Belem, pp.259-269	Air	MAG	GS(+2)	△
22	Hocker, E.C.	1980		Metodos Geofísicos Aplicados Á Prospecção de Cobre na Serra dos Carajás, UF Pa/Teste/	Ground	EL(IP)	METAL (+3)	○
23	Hooker,E.C.,Rocha,B.R.P. da, and Sauk, W.A.	1980		Geofísica aplicada à área Alvo 1,MM1, Serra dos Carajás, Anais do XXXI Congresso Brasileiro do Geologia, V.2., pp.1166-1177	Ground	EL(IP)	METAL (+4)	○
24	Rocha, B.R.P. da, and Sauk, W.A.	1982		Medidas de Condutividade Elétrica Complexa de Amostras de Rochas da Área MM1-Alvo 1-Distrito dos Carajás, Revista Brasileira de Geofísica, Vol.1, pp.1-9	Ground	EL,EM	METAL (+5)	○

*1 P-1, 2, 3 and 21 belong to the same project (Projeto Geofísica Brasil-Canadá)

*2 P-4 and 5 are the same project (Projeto Sul do Para)

*3 Method — MAG:magnetic, RAD:radiometric, EL:electric (SCH:Schulumberger, IP:induced polarization, SP:spontaneous potential, MM:mise-à-la-masse), EM:electro-magnetic (CEM:Crone EM, INP:INPUT, VLF:very low frequency, AFMAG:audio-frequency magnetic), and REI:Re-interpretation of the existing geophysical Data

*4 Purpose — TR:training Brazilian Engineers, METAL:metallic ore deposit exploration, PET:petroleum exploration, UR:uranium ore deposit exploration, GEOL:geological mapping, NR:natural resources survey, WAT:groundwater resources survey and GS:geological structure survey, (+1):obtained only schedule, (+2):using PGBC data, (+3):master thesis, (+4):summarized edition of P-22, and (+5):measurement of physical properties of drilling cores in Carajás area

*5 Pos:Possibility of Utilization for Analysis:
○ :possible, △ :partially possible and X :impossible