REPORT ON

MINERAL RESOURCES DEVELOPMENT

BRAZIL

AUGUST 1970

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OVERSEAS TECHNICAL COOPERATION AGENCY
GOVERNMENT OF JAPAN

JAPANESE SURVEY TEAM FOR MINERAL
RESOURCES DEVELOPMENT

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by

JAPANESE SURVEY TEAM FOR MINERAL
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PREFACE

The Government of Japan, in compliance with the request of the Government of Brazil, entrusted the Overseas Technical Cooperation Agency the execution of survey for mineral development in Brazil.

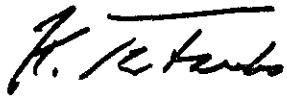
In view of the importance of the project, the OTCA organized a survey team consisting of six experts headed by Mr. Tadao Hamachi, chief of Survey Division, Metalic Minerals Exploration Agency of Japan.

The Team carried out field survey for about 40 days on the nickel deposit in Niquelândia, Goiás State and on the coal field near Carolina, along the Upperstream of Rio Tocantins in Goiás and Maranhão State.

It is our sincere hope that this report will prove to be usefull in contributing to the development of mineral resources in Brazil and at the same time contribute to the promotion of goodwill between our two countries as well as the cementing of technical and economic relations.

Finally, I would like to take this opportunity to express my sincere appreciation and gratitude to the officials of the Government of Brazil and organizations concerned.

August, 1970



Keiichi Tatsuke
Director General
Overseas Technical Cooperation Agency

C O N T E N T S

Figures

REPORT ON

GEOLOGICAL SURVEY FOR MINERAL RESOURCES DEVELOPMENT

OF

THE FEDERATIVE REPUBLIC OF BRAZIL

I. Introduction

The Brazilian Government expressed the hope to carry out a survey for development of mineral resources of Brazil as one of the economic cooperations between Japan and Brazil when the Economic Survey Team for Six Countries of Central and South America visited Brazil in October, 1967.

Later in August 1969, Dr. Dias Leite, the Minister of Mines and Energy, requested through the Japanese Ambassador that Japan conducts a development plan based on the technical cooperation program to be implemented in the most favorable way for both countries.

Finally in January, 1970, Dr. Benjamin Batista, the Vice-Minister of Mines and Energy, met Mr. Y. Tokugawa, the First Secretary of the Japanese Embassy, and requested the dispatch of a Japanese geological survey team for the purpose of surveying the nickel ore deposits in the Niguelândia district, Goiás State, and the coal field near Carolina, along the upper stream of Rio Tocantins in Goiás and Maranhão States. In response to the request, the Japanese Government sent a Survey Team for mineral resources development in Brazil for a period of forty days from February 17 to March 28, 1970.

Upon its arrival in Brazil, the Japanese Survey Team was requested by the Minister Dias Leite to place emphasis on the following two items.

(1) To make final evaluation of the coal field along Rio Tocantins which has been considered not so promising from the past survey results.

(2) To examine a future possibility of carrying out a basic survey by the Japanese Government, based on an agreement between both Governments, in the Northern Goiás State north of latitude twelve degrees south where there are some possibilities of occurrence of nickel, copper, asbestos platinum and tin.

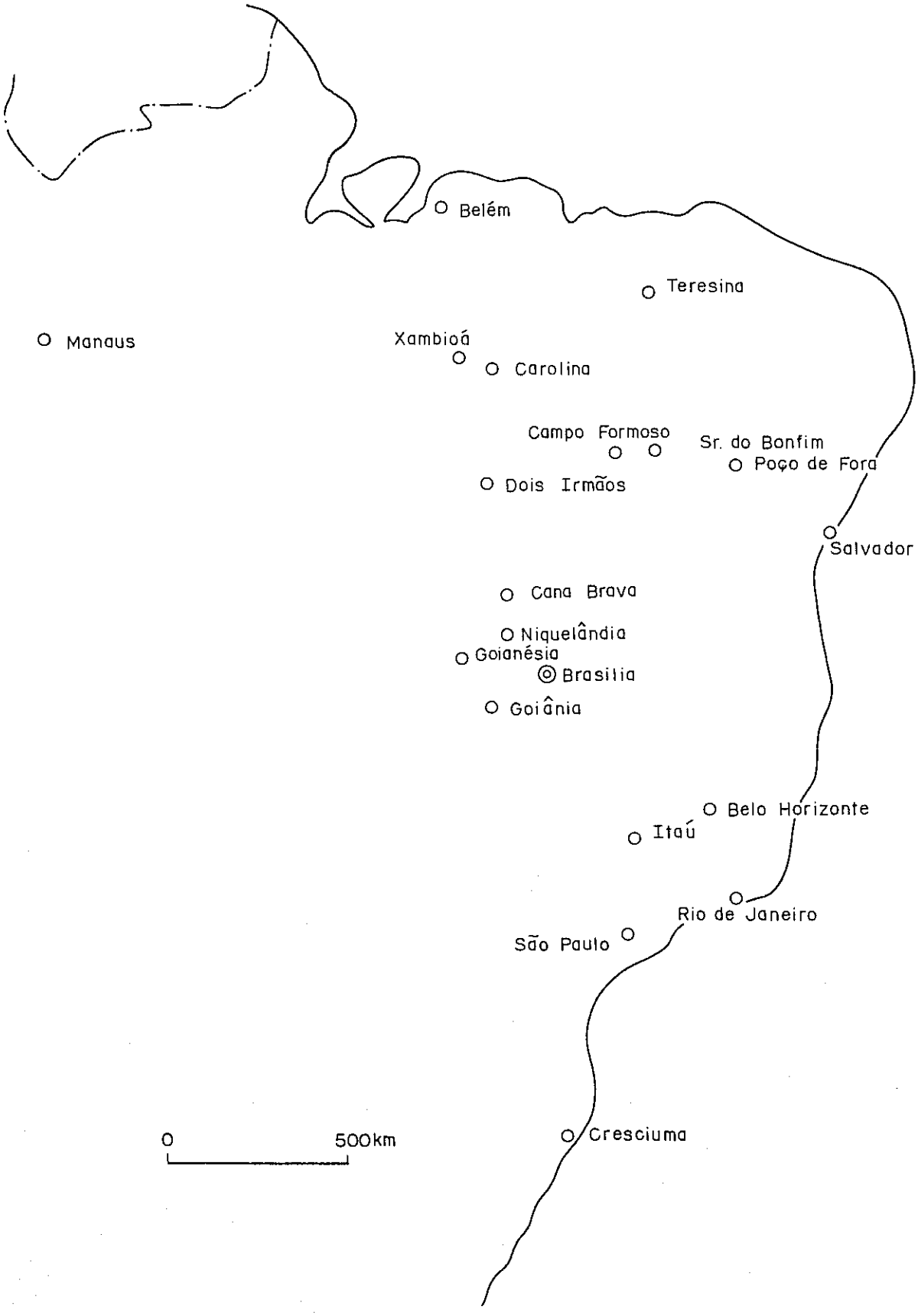


Fig. 1 Index map of visited places in Brazil

The Survey Team was divided into two parties for coal and metals to carry out an efficient survey. For better evaluation and examination, both parties visited coal fields and metal mines not included in the original survey itinerary.

The members of the Survey Team are the following six mining engeneers and geologists.

Hisashi OKI	(Adviser)	: Overseas Mineral Resources Development Co., Ltd.
Tadao HAMACHI	(Chief)	: Metallic Minerals Exploration Agency of Japan
Isamu SHIMIZU		: Overseas Coking Coal Development Co., Ltd.
Kazumasa SAWATA		: Overseas Coking Coal Development Co., Ltd.
Hideo OTSU		: Sumitomo Mining Consultant Co., Ltd.
Akira YATSUJI		: Overseas Mineral Resources Development Co., Ltd.

The survey was accomplished with the kind assistance and cooperation extended by the Ministry of Mines and Energy, Federative Republic of Brazil and the Embassy of Japan in Brazil, to whom the Team wishes to express its deep gratitude.

II General geology

About two thirds of the Brazilian territory are made up by Precambrian rocks which are entirely reduced to the cratonic areas some 500 million years ago. The cratons are called Guiana, Central Brazilian (Guaporé) and Atlantic (São Francisco) cratons and three sedimentary basins develop between them after the Early Paleozoic.

These intercratonic basins are called respectively Amazon basin, which is located in the Amazon River basin between Guiana and Central Brazilian cratons, Meito Notre basin, which is divided into Parnaiba and São Francisco basins and distributed between Central Brazilian and Atlantic cratons, and Paraná basin between Central Brazilian and Atlantic cratons.

Besides the three intercratonal basins there is a sedimentary belt along the Atlantic coast extending under the Atlantic Ocean and subdivided into grabens.

1. Precambrian basement

The oldest basement in Brazil was found in Guiana craton and its age is estimated to be about 3,000 million years after K-Ar method. The lower precambrian rocks, which are classified as precambrian (D) in the geologic map of Brazil with a scale 1 to 5 million published in 1960, are generally composed of gneissose rocks, migmatite, charnockite and amphibotites, etc. accompanied by acidic-ultrabasic intrusives and are called crystalline basement or complex, which shows 2,000 million 2,500 million years in age at some localties.

The precambrian (c) represents so-called Pre-Minas series which is generally composed of mica-schist, phyllite, quartzite, grey-wacke and conglomerate with acidic-ultrabasic rocks, and, for instance, its age is older than 1,350 million years in Minas Gerais State. Some localities of the Precambrian (c) and (d) show 2,000 million years in age. But it is sometimes not correct to correlate the age based on apparent metamorphic grade, and the knowledge of the Precambrian (c) and (d) is expected to be increased by further investigations.

The Precambrian (B) and (A) represent the Upper Precambrian and for instance, the Minas and Itacolomi series in Minas Gerais State, which are composed of both clastic and chemical sediments, are though to have been deposited 1,350 to 500 million years ago. It is very interesting that the rocks showing 500 - 700 million years in age are distributed in the periphery of the Brazilian shield.

Fig. 2 South American geotectonic unit

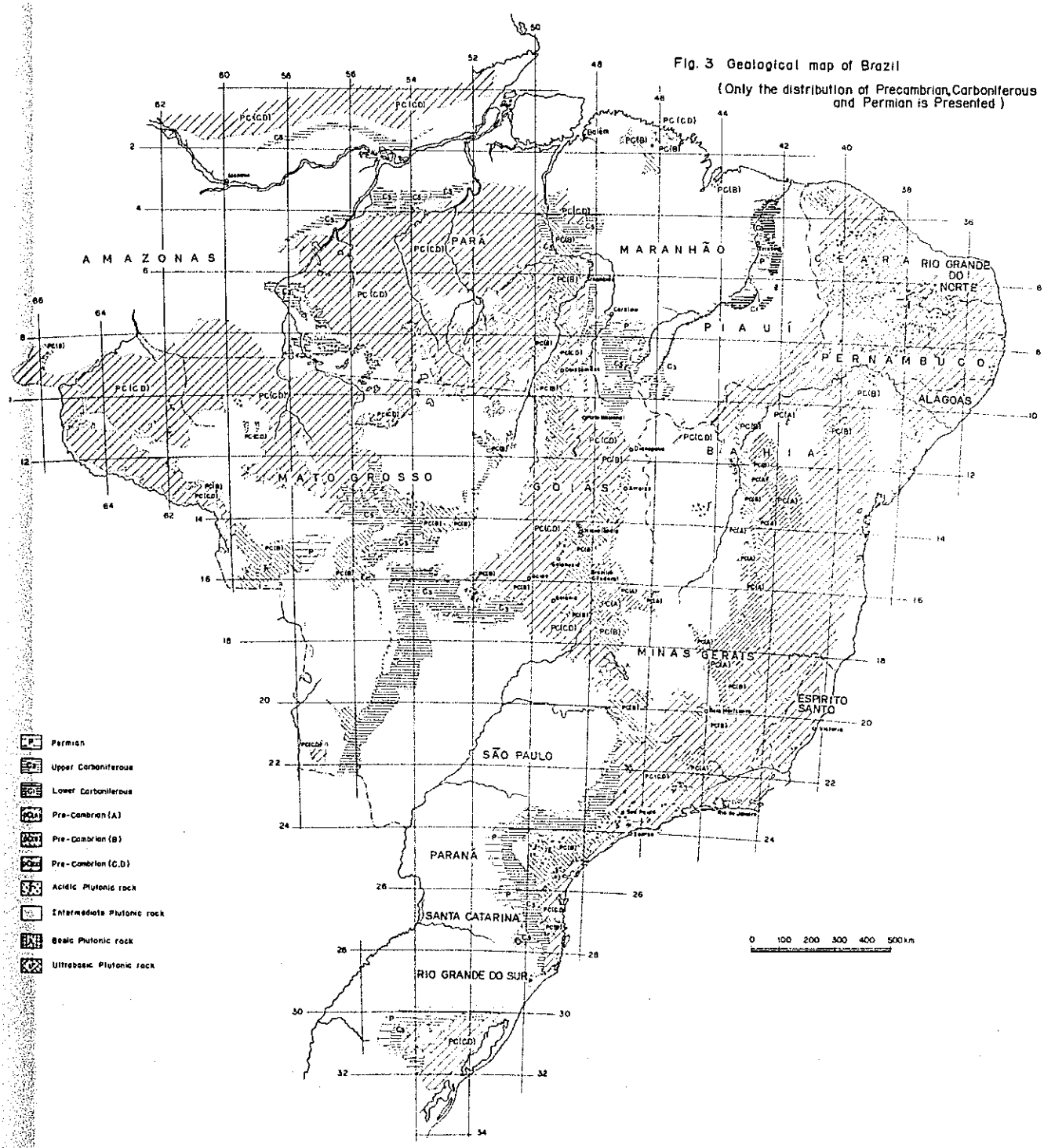


Fig. 3 Geological map of Brazil

(Only the distribution of Precambrian, Carboniferous and Permian is Presented)

The Precambrian structures are parallel to the eastern and southern Brazilian coast lines, and, on the other hand, unconformable with the northeast coastline. Also the Paleozoic sedimentary basins already mentioned are adopted to the Precambrian structures.

2. Intercratonic basin

In Fig. 2, the arrangement of the cratons is South America is shown. Each craton is separated from one another by the bordering areas, which were occupied by the intercratonic basins developing between cratons.

Four intercratonic basins are well descriminated, and they are called as follows:

Paraná basin
Amazon basin
Parnaiba basin
São Francisco basin

Three of these four intercratonic basins (Paraná, Parnaiba, and Amazon basins) are related to the coal depositions in the Carboniferous ~ Permian Period. The São Francisco basin has no coal bearing formation because the sedimentary basin did not develop through the Paleozoic era.

1) Paraná basin

The Paraná basin, which occupies the southern part of Brazil, extends to the northern extreme as far as Mato Grosso State, and its western margin extends as far west as Paraguai and Uruguai.

The geologic age of the sediments distributed in this basin ranges for a long period from early Devonian to Cretaceous. The Carboniferous system is distributed on both margins of the basin, and that of the eastern margin is well divided into two formations, that is, the coal bearing formation for the upper part and the glacial formation for the lower part, though in the western margin of the basin, the glacial sediments intercalated by the sandstone bed, represent the whole Carboniferous period. The correlation between the two sequences distributed in both margins are not yet determined up to the present.

The coal deposits of the eastern margin of this intercratonic basin have been already explored, though in some localities spontaneous explorations are still carried out, and the main coal production in Brazil comes from this coal field.

2) Parnaiba basin

The Parnaiba basin, which occupies a part of the northern and northeastern districts in Brazil, extends over the whole area of Piauí and Maranhão States and part of Pará and Goiás States.

In the southern extension of the Parnaiba basin, there is another intercratonic basin, namely São Francisco basin, which was connected to the Parnaiba basin after Triasic Period, through the pass of the invasion sea. The sedimentation from Trissic through Crataceous overlapped the underlying Paleozoic sequences.

The Carolina Coal Project area is located in the southwestern margin of the Parnaiba basin. There is another promising coal project area in this intercratonic basin which is located in the eastern margin of this basin. Teresina and its neighbouring area seem to be a promising coal field of Brazil in the near future.

3) Amazon basin

The Amazon basin covers a part of the States of Pará and Amazonas, and it occupies the basin of Amazon River.

The deposition in this intercratonic basin ranges in geologic age from Silurian to Tertiary. The Carboniferous and Permian sediments, so far as seen in the Amazon river area, show the facies of marine sediments in origin, and are enriched in the petroleum resources. The lignite bearing formation was found in the Tertiary sediments of this basin in the limited locations along the tributaries of the Amazon River.

III Geology and mineral deposits in Goiás State

1. Geology

Goiás State is made up by the Precambrian basement rocks and a part of two sedimentary basins after the Early Paleozoic.

As to the geology of Goiás State, there is only two publications, that is, geological map of Brazil (1960) with a scale of 1 to 5 millions, and a geological map of the Araguaia Project (1966) with a scale of 1 to one million covering the area of latitude 5-12 degrees S. from north to south, and between Rio Tocantins, Goiás State, and Rio Xingu, Pará State from east to west, and the data are too poor to analyse the geological circumstances.

Goiás State is located just in the southeastern part of the Central Brazilian Craton. The southwestern part of the State corresponds to the northern margin of the Parana basin, and in the eastern and northeastern part, the western margin of the São Francisco basin and the southwestern margin of the Parnaiba basin cover the Precambrian basement rocks.

In the Paraná basin area, sediments and some volcanics from Devonian to Cretaceous are distributed, and in the Parnaiba basin area, sediments from Devonian to Cretaceous are distributed, while in the São Francisco basin area, sediments from Triassic to Cretaceous are distributed. The area where the silulian shown in the geological map of Brazil is distributed changed to Eocambrian Banbui series (500-600 million years) composed of conglomerate, quartzite, arkose sandstone, siltstone, argillites intercalated with limestone, marl and chert and phyllitic in some localities. The area between the São Francisco and Paraná basins was separated by the Candstra Arch running NW-SE during the Paleozoic Era.

According to the geological map of Brazil, the Precambrian basement rocks are divided into (C, D), (B) and (A) in ascending order.

(D) of (C, D) is gneissose basement rock, (C) is Pre-Minas series, (B) is Tocantins series and (A) is Itacolomi series respectively. The classification of the Precambrian rocks in Minas Gerais State which is comperatively well researched is as follows.

Itacolomi series	quartzite, phyllite, conglomerate, etc.
Minas series	mica-schist, graphite, quartzite, grey-wacke conglomerate, chert, itabillite, dolomite, etc.

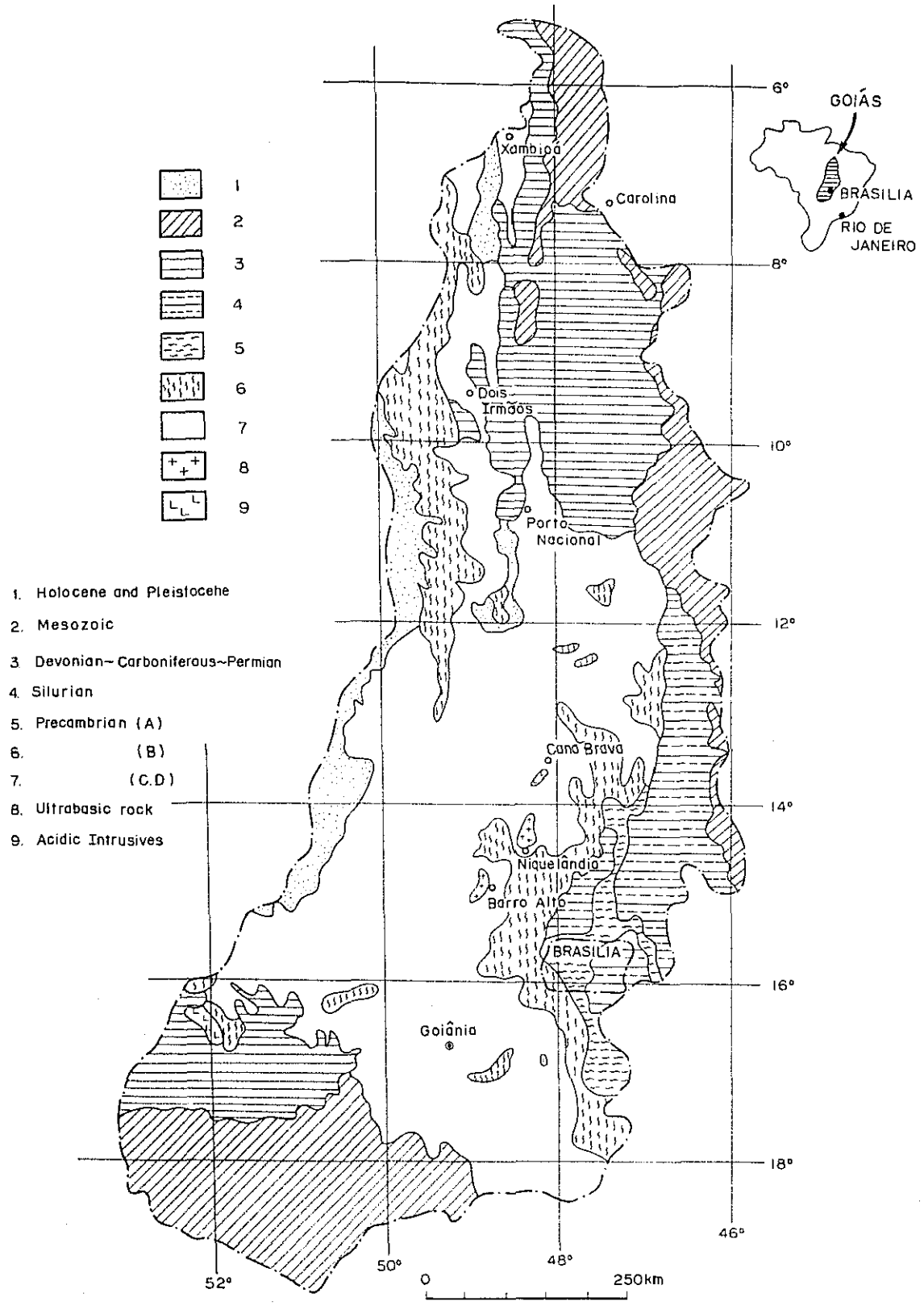
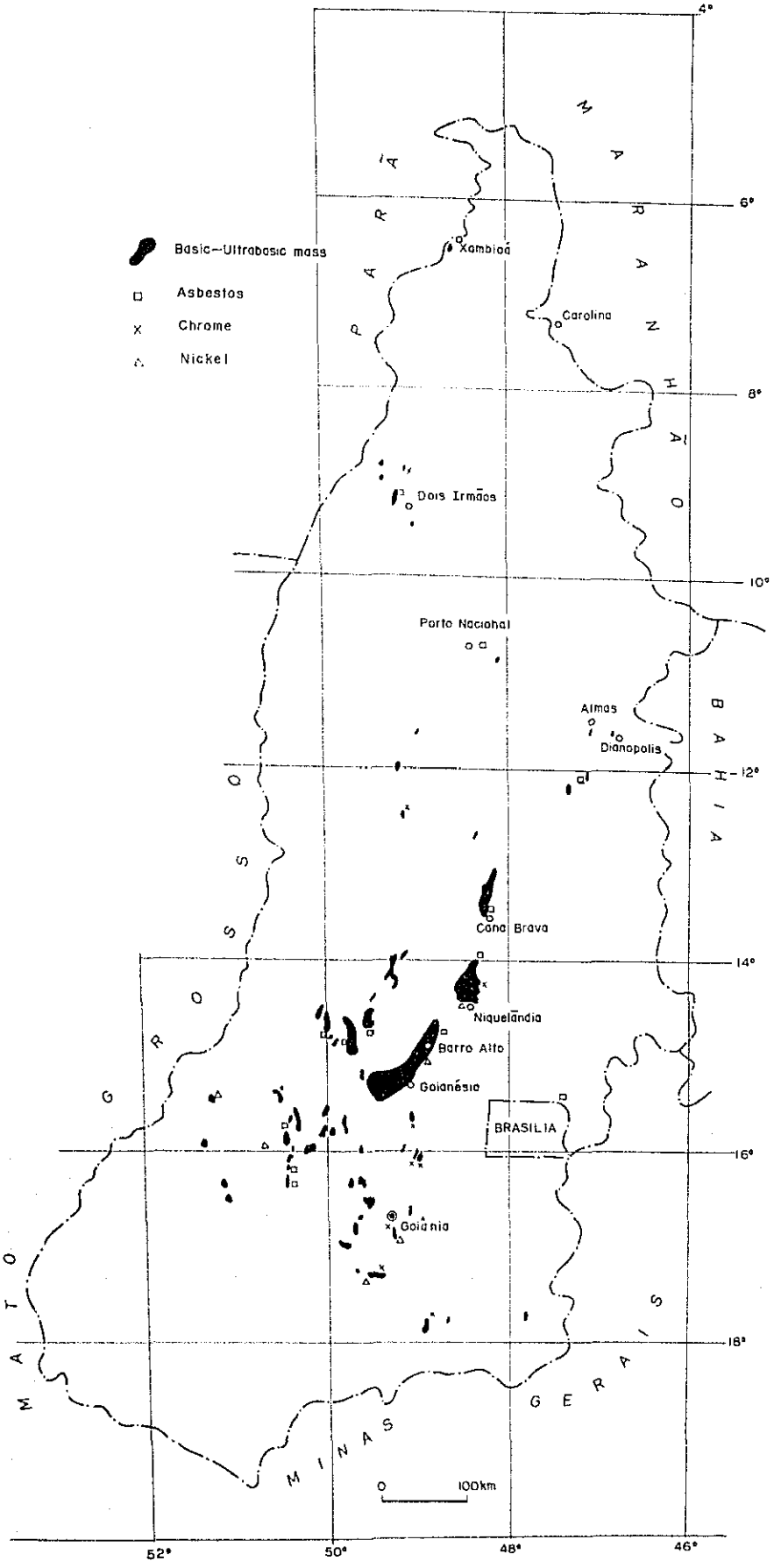


Fig. 4 Geological map of Goiás State (After Mapa Geológico do Brasil 1:5,000.00,1960)

Fig. 5 Map showing occurrences of basic and/or ultrabasic masses, nickel, chrome and asbestos in Goiás State



Rio Das Velhas series	mica-schist, phyllite, quartzite, conglomerate, greywacke, lenticalar iron and manganese ore, etc.
Mantiqueira series	banded gneiss, amphibolite, etc.

The Mantiqueira series is older than the Engenheiro Corrêa grandiorite with 2,400 million years in age and belongs to the lower Precambrian (Archean). The Rio Das Velhas series clinouncomformably covering the Mantiqueira series is partly thermally metamorphosed by the Itabirito granite with 1,350 million years in age and belongs to the Middle Precambrian. The Minas series overlying clinounconformably the Rio Das Velhas series and the Itacolomi series overlying also clinounconformably the Minas series are intruded by the Itabila granite with 500 million years in age and belong to the Upper Precambrian. The old three series are deposited under geosynclinal environment, and the Rio Das Velhas series is thought to be eugeosynclinal while the Minas series is miogeosynclinal. The Itacolomi series is deposited under terrestrial environment.

Therefore, (C) of (C, D) of the precambrian in Goiás State, Pre-Minas series, should indicate the Middle Precambrian, (B) the lower part of the Upper Precambrian and (C) the Upper part of the Upper Precambrian, though the Araxá series included in (C, D) is around 1,200 million years in age.

The Precambrian in Goiás State is divided tentatively into the following:

Araí series	quartzite, arkose sandstone, conglomerate, partly andesite, basalt, etc.
Tocantins series (Canastra)	light green coloured quartzite, limestone, quartz-itabilite, etc.
Araxá series	mica schist, amphibolite, gneiss, calcareous schist serpentinites, granitic rocks, etc.
Individed basement rocks	gneiss, migmatite, granitic rocks, amphibolite, etc.

The Tocantins (Canastra) series corresponds to the area of (B) and the Arai series shows the area of (A) respectively. But the distribution of the divided Precambrian indicates only a general idea, and the geology in Goiás State is under revision from the results of the Brazilia and Goiânia projects which have been almost accomplished.

In the Central Goiás, the Intermediate Mass of Central Goiás (Macico Intermedario de Goiás Central) is widely distributed, which is divided into the Basal Complex and Araxá series estimated to correspond to Middle Precambrian and partly older in age. The Basal Complex is composed of migmatite, biotite-

gneiss and hornblendegneiss accompanied with cataclastic granitic rocks. The Araxá series belongs generally to greenschist facies and is locally metamorphosed to kyanite and sillimanite bearing garnet-biotite schist accompanied by migmatite. The Araxá orogenesis (Uruaçua folding belt) indicates an evolution of eugeosyncline which develops between the Guaporé and São Francisco platforms.

Two miogeosynclines develop along the above-mentioned platforms in the eastern and western sides of the Uruaçua folding belt, and the eastern one is called Brazilia miogesyncline and the western one is called Paraguai-Araguaia miogeosyncline, both of which show partly characteristics of Flysch type.

Tocantins and Canastra series represent respectively a part of Paraguai-Araguaia and Brazilia miogeosynclines.

According to recent investigations of absolute age, the Basal Complex and Araxá series are 1,200 million years or older in age, and, on the other hand, the Tocantins and Canastra series are several million years in age.

General trend of the Precambrian rocks shows around N-S, though the NW-SE direction is predominant in the area between the São Francisco and Paraná basins.

The Araxá series which has often ultrabasic~basic masses is widely distributed at least in the Brazilia project area from lattitude 12 degrees to 15° degrees 15 minutes S. The distribution of basic~ultrabasic masses is shown in Fig. 4.

Many serpentinized ultrabasic masses occur well concordantly with the trend of the Araxá series. The fact that the secondary planar and linear structures of serpentinite are concordant with those of the surrounding schists and the nodular chromite deposits show generally cataclastic texture suggests that the serpentinized masses belong to the "Alpine type" (Thayer 1960) which develops in the central zone of eugeosynclinal orogeneses.

Three large masses of basic complexes develop in the NNE-NE direction the largest one of which occurs near Barro Alto and Goianésia and has about 90 km length. These masses are well differentiated from ultrabasic (perridotite and serpentinite) to anorthosite with gradual boundaries between respective rock facies and seem to have concordant with the Araxá series especially in the both sidewalls, and they seem to have common characters of both "Alpine type" and "stratiform" poridotitegabbro complexes.

2. Mineral deposits

Ninety localities are now under exploration for minerals and thirty five of them are productive.

Mineral production in 1968 is as follows:

	ton	1,000 Ncr$
Asbestos	67,242 (345,442)	698 (1,289)
Chromite	1,600 (17,032)	55 (677)
Cassiterite	3 (2,810)	12 (15,302)
Garnierite	360 (67,744)	1 (230)
Rutile	284 (284)	124 (124)
Graphite	216 (22,000)	50 (2,029)
Rock crystal	556 (1,182)	2,659 (4,034)
Mica	200 (484)	50 (187)

Numbers in paranthesis show mineral production of the whole Brazil.

It is quite clear that asbestos, rutile and rock crystal in Goiás State occupy an important position of the mineral production in Brazil.

Given below is the brief description of the mineral deposits in Goiás State visited by the Survey Team.

(1) Goianésia-Barro Alto area

A basic complex with about 90 km length and 20 km width is distributed in the Araxá series, running in the NE-SW direction, and it is called Goianésia-Barro Alto complex. It dips steeply to NW and the banded fine-grained gabbro in the SE side and hornblendite in the NW side are respectively distributed.

Basic charnockite is distributed in the western margin of the complex and serpentinite occurs in the central part of the northeastern area of the complex.

Asbestos and nickel occur in serpentinite, but, mineralized area is of small scale. Garnierite veinlets develop partly in weathered serpentinite, though garnierite could not be observed in the laterite zone with 1 - 4 meters thickness on serpentinite.

(2) Niquelândia area

A basic complex with about 45 km length and 25 km width runs in the Araxá series in the NNE direction from the north of Niquelândia. It dips to NW and is divided into several zones from SE to NW, that is, from lower to upper, as follows.

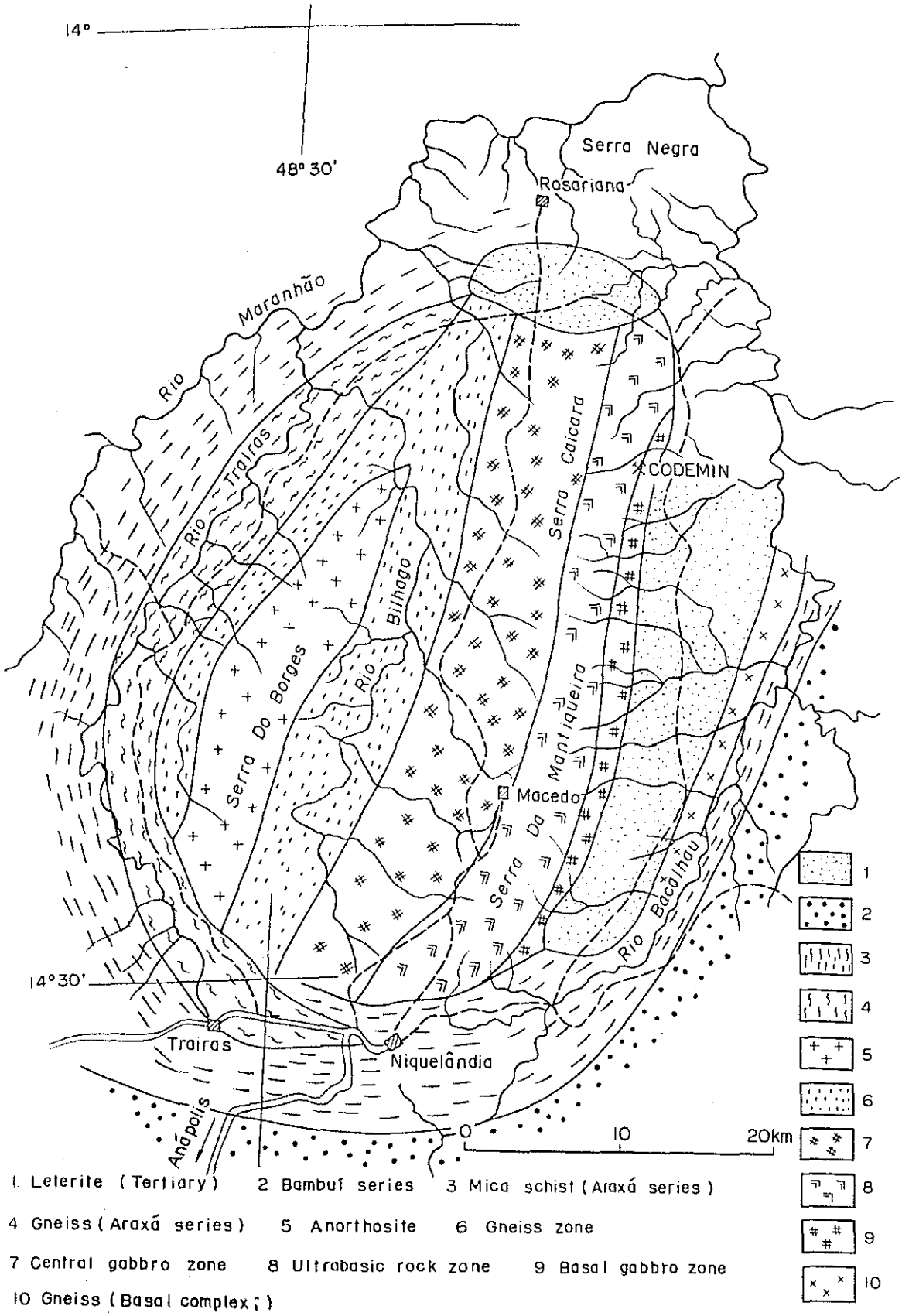


Fig. 6 Schematic geological map of the Niquelândia area, Goiás

1. Basal gabbro zone
2. Ultrabasic rock zone
3. Central gabbro zone
4. Gneiss zone
5. Anorthosite zone

The ultrabasic zone which has an intimate relation to the nickel deposit is 3 - 6 km wide and is composed of peridotite and websterite often serpentinized.

The Araxá series is generally composed of mica-schist, but is composed of gneiss showing epidote-hornblend facies in the NW contact zone with the basic complex. The basic complex is concordant with the Araxá series in the NW side, though the relation between both cannot be observed because of covering of Tertiary laterite in the SE side.

The nickel deposits belonging to "Companhia de Niquel do Tocantins" were already described by W.T. Pecora in 1944. A schematic columnar section of Jacuba No. 2 ore deposit is described as follows.

	Maximum thickness (m)	Ni (%)
Pebble clay	1	
Red clay	6	0.5-1.0
Transition	3	
Purple clay	15	0.5-1.5
Transition	5	
Green clay	25	2.0-5.0
Transition	8	0.1-1.0
Pyroxinite		0.1-0.2

Forty-five individual nickel-silicate deposits were indicated by prospecting works in 1942 and those deposits show a peculiar distribution. The nickel-silicate deposits always lie on pyroxenite or peridotite forming topographic saddles between serpentinized ridges top of which is covered by blocks of a sponge-like chalcedonic rock.

Malachite was already identified by Pecora, and the fact that the ores include 0.2-0.7 per cent copper has been verified from the result of chemical analyses of the samples decribed later.

The nickel deposit which is yelow clay on weathered serpentinite with-

out green garnierite is now prospected by the same company in the Angiquinho area.

The primary sulfide minerals such as pyrrhotite, pentlandite and chalcopyrite have been recently found in fresh pyroxinite of drill cores and this suggests that the common distribution of copper in the nickel-silicate ores is originated in chalcopyrite.

In the northernmost part of the ultrabasic rock zone, the prospecting works are carried out by "Empreza de Desenvolvimento Minerais (CODEMIN)", but, it is impossible to recognize the occurrence of garnierite in yellow clay on weathered serpentinite, though nickel content is 1.1 per cent after chemical analyses.

(3) Cana Brava area

A basic complex with about 55 km length and 10 km width is distributed between Rio Maranhão and Rio Cana Brava. The asbestos deposits occur in serpentinite of the southernmost part of the complex and are mined by "Mineracão de Amianto SA" . They are cross-fiber deposits with a length of 0.7 mm-1 cm of chrysotile and an average grade of 7 per cent. The mine is the only chrysotile producing mine in Brazil.

(4) Dois Irmãos area

Only chromite and peridotite blocks were observed lying on the Araxá series, and no ultrabasic masses have yet been discovered.

(5) Xambioá area

There are numerous rock crystal bearing placer deposits on the bank of the Rio Tocantins, and one of the visited deposits is weathered pegmatite in the Araxá series.

(6) Chemical analyses

The result of chemical analyses on the collected samples is as follows:

Location	Name of samples	Ni(%)	Cu(%)
Niquelândia area			
Jacuba No. 1 deposit	Green clay	2.1 (0.84)	1.9 (0.27)
Jacuba No. 2 deposit	Slit Sample	2.8 (1.72)	11.0 (1.90)
Angiquinho	Laterite	1.9 (0.56)	0.6 (0.25)
	Weathered serpentinite	1.8 (0.33)	1.4 (0.01)
CODEMIN	Weathered serpentinite	1.1 (1.00)	0.2 (0.01)

Barro Alto area			
CIA. Min. de Ferro e Carbao	Weathered serpentinite	2.1 (0.56)	0.0 (0.00)
	Laterite	1.5 (0.52)	1.1 (0.01)
	Manganese nodule	1.8 (0.52)	3.9 (0.01)
	Weathered serpentintie	1.8 (0.46)	0.0 (0.00)
Cana Brava area	Laterite	1.7 (0.51)	2.3 (0.01)
Morro de Niquel	High grade ore	3.2 (2.85)	0.0 (0.00)
	Low grade ore	1.4 (0.86)	0.0 (0.00)

Analyst: Takao Komaki, São Paulo University

Numbers in parenthesis are the result obrained by chemical analyses by H. Otsu.

The differences are partly due to heterogeneity of samples.

3. Possibility of occurrences and development of mineral deposits in the northern part of Goiás State

(1) Possibility of occurrences of mineral deposits

The possibility of occurrences of mineral deposits associated with basic-ultrabasic masses can be estimated only by the geological data of the area south of latitude 12 degrees S.

According to the geological map of "Brazilia Project" with a scale of 1:1 million not yet published, in the major Precambrian part of the southern part of the State is distributed the Araxá series where the large basic complexes such like Cana Brava, Niquelândia and Barro Alto-Goianésia exist. The general structural trend of the Precambrian rocks is around N-S, and therefore it is sure that there is distributed rather widely the Araxá series in the Northern Goiás State.

As to the occurrences of basic-ultrabasic masses, two bodies near Dianopolis and Rio Manoel Alves (near latitude 11°40'S and longitude 47°W), one body near 40 kilometers southeast to Porto Nacional (latitude 11°S and longitude 48°10'W), five bodies near Dois Irmaos-Araguacema (latitude 8°50-9°30'S and longitude 49°-49°20'), and one body southwest to Xambioá have been already confirmed, and parts of them accompany asbestos and chrome.

As for nickel, the occurrence has not yet been known, while in the southern part of the State there are many occurrences. In the northern part of the State, both humidity and temperature are higher than in the southern

part of the State. Therefore, there is many chances of occurrence of the residual deposits like the nickel-silicate ore deposits on the ultramafic masses, if the topographic condition is favorable.

The ore deposit of "Morro do Niquel" mine, Pratapolis, Minas Gerais State, which produces about 1,000 tons nickel as ferro-nickel, lines on serpentinite body with about 900 meters in long diameter and about 400 meters in short diameter and is estimated to have about 770 thousand tons with 2.2 per cent nickel as visible ore reserve, 3,250 thousand tons with 1.6 per cent nickel as probable ore reserve and 10 million tons with 1.5 per cent nickel (after Ernst Lange 1969). Therefore, it is expected that the nickel-silicate ore deposits with larger dimensions may exist in the northern part of the State.

As to copper, only one locality is known near Porto Nacional, but the details are obscure. The copper occurrence in the nickel-silicate ore deposits near Niquelândia was already described by W.T. Pecora (1944). It is very peculiar that copper is widely distributed in the nickel-silicate ore deposits on the ultramafic mass near Niquelândia, while the nickel silicate-ore of "Morro Do Niquel" mine includes no copper (0.00 per cent). The copper in the nickel-silicate ore of the Niquelândia district is not originated in rock-forming minerals composed of ultramafic rocks, but in chalcopyrite recently found in the drill core in the Niquelândia district. Disseminated primary sulfides such as pyrrohitite, chalcopyrite and pentlandite have been affirmed in the drill core, and this indicates the Niquelândia ultramafic mass includes generally primary copper sulfides, though none economically valuable has yet been found.

It is well known that there are many occurrences of copper associated with ultramafic bodies in the Caraiba district, Bahia State, and the copper deposit of Caraiba mine is estimated to have 23×10^6 tons crude ore with 1.4-1.6 per cent copper content. However, it is very difficult to prognoscate the existence of economic copper deposits in Goiás State.

A detrital chrome ore deposit has been found near Dois Irmãos by Magnesita S.A. though the outcrop of original country rock has not yet been found. The occurrence of chromite as well as asbestos is also expected in the northern Goias State.

(2) Possibility of developing mineral deposits

There are no railway nor paved road in the northern Goiás State. A main national road runs from Goiânia to Belém across the rather western part

of the State in the N-S direction, and the electric power line reaches just near Goianésia.

In the Cana Brava asbestos mine, which is only one active large mine situated a little north from lattitude 14 degrees S, the transportation of concentrated asbestos to Goiânia on the almost unpaved road of 640 km costs about 22 US dollars per ton and that from Goiânia to São Paulo on the completely paved road of about 900 km costs about 11 US dollars per ton.

It is impossible to produce high grade concentrate from nickel silicate ore. Since it is clear from the price of nickel that transportation of the crude ore from the northern Goiás State is unprofitable, the smelting in the mining place is the only way to develop the nickel-silicate deposit.

IV Coal projects in the northern Brazil

The exploitation activities for coal deposits in the northern Brazil were carried out in cooperation with the State Institute, the Federal Research Organizations and contractors with the promotive assistance of CPCAN.

Four areas shown below, were already taken up by the Federal Government, and the research activities have been executed over the past few years.

1) Amazon (Solimoes River) area	in 1966
2) Xingu River Project	in 1967 - 1969
3) Carolina Coal Project	in 1967 - 1969
4) Teresina Coal Project	in 1970 -

1. Amazon area

The project area is located in the Upper Amazonas (River Solimoes) where the lignite deposits were ascertained in the drilling carried out by PETROBRÁS. The investigations for the coal deposit planned by CPCAN were executed by the survey party of OTTO GOLD Co. & COMPEQUE in 1966. But the results obtained were unfortunately negative, because only the occurrences of lignite with small thickness and without any economic value were ascertained.

2. Xingu River Project

In Rio Fresco region in Pará State, there exists a relatively small sedimentary basin covering the river banks of the tributary of the Xingu. To get an evidence in respect of the eventual amount of reserve, CPCAN, in agreement with the IDESP led the geological survey for the coal deposits in this area, and the survey teams from IDESP were sent to this barbarous region on several occasions through the years from 1967 to 1969.

The expeditionary works operated in this field were enforced under the systematic planning of IDESP. Through this survey activity, the air photographs were used for making route maps, identification of rock facies, interpretation of geologic trend and structures and so on. But the result obtained was not positive for the coal resources. There was only the limited existence of small coal reserves, and the quality of the coal collected in this field showed the same analytical values as those of anthracite.

3. Carolina Coal Project

Carolina Coal Project and is situated on the southwestern border of

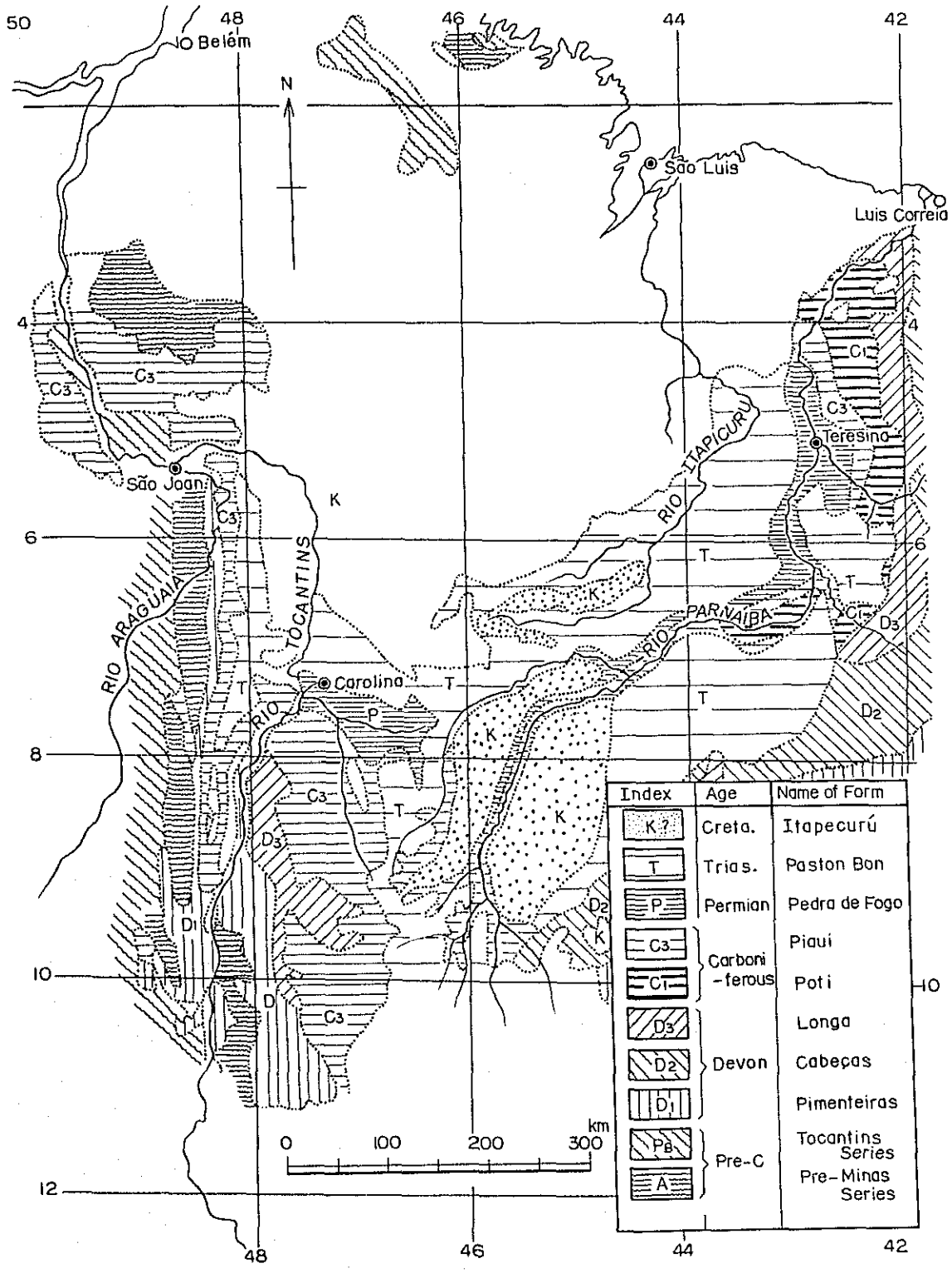


Fig. 7 Geological map of Parnaiba coal basin

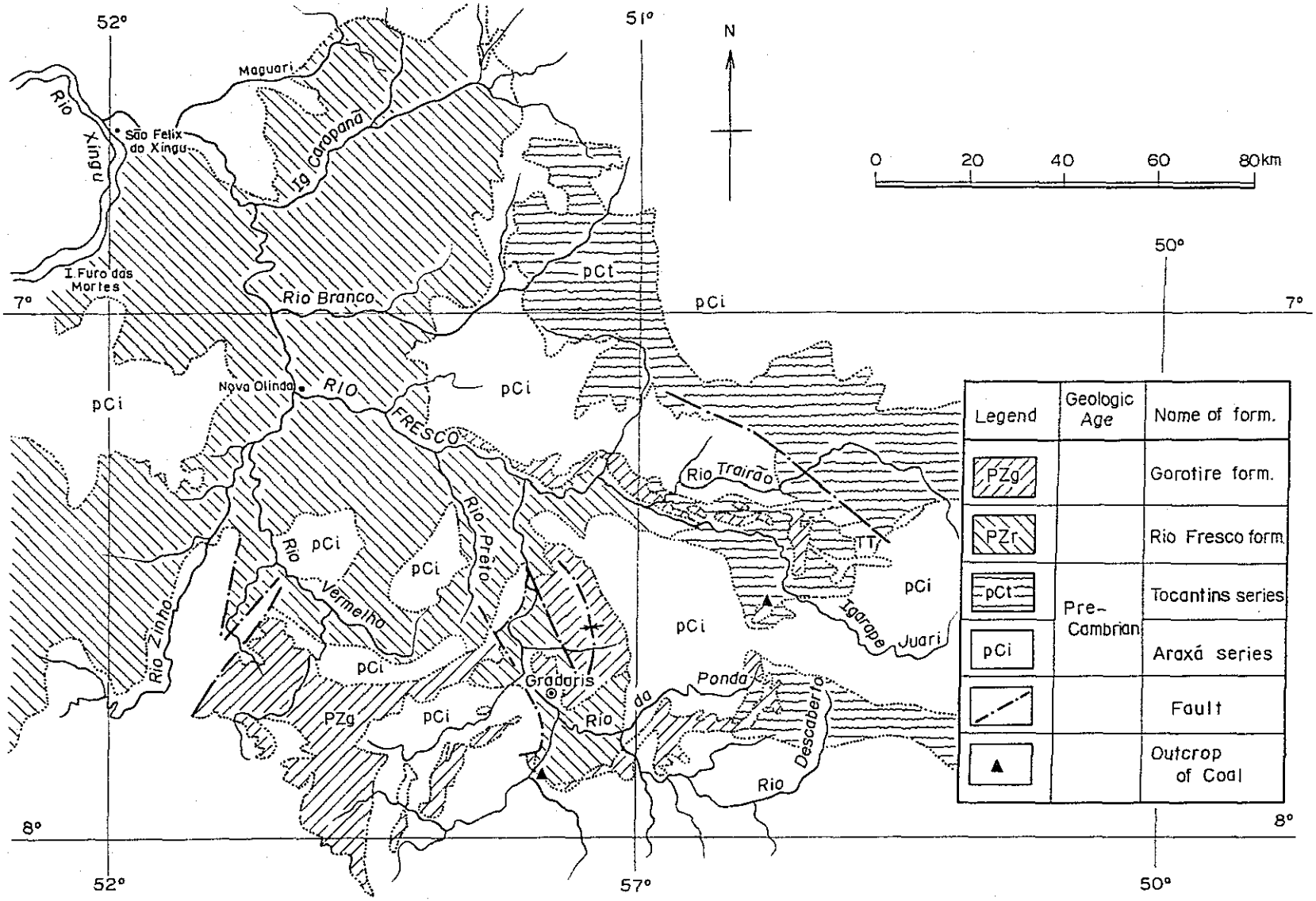


Fig. 8 Geological map of coal project in Rio Fresco area, Pará

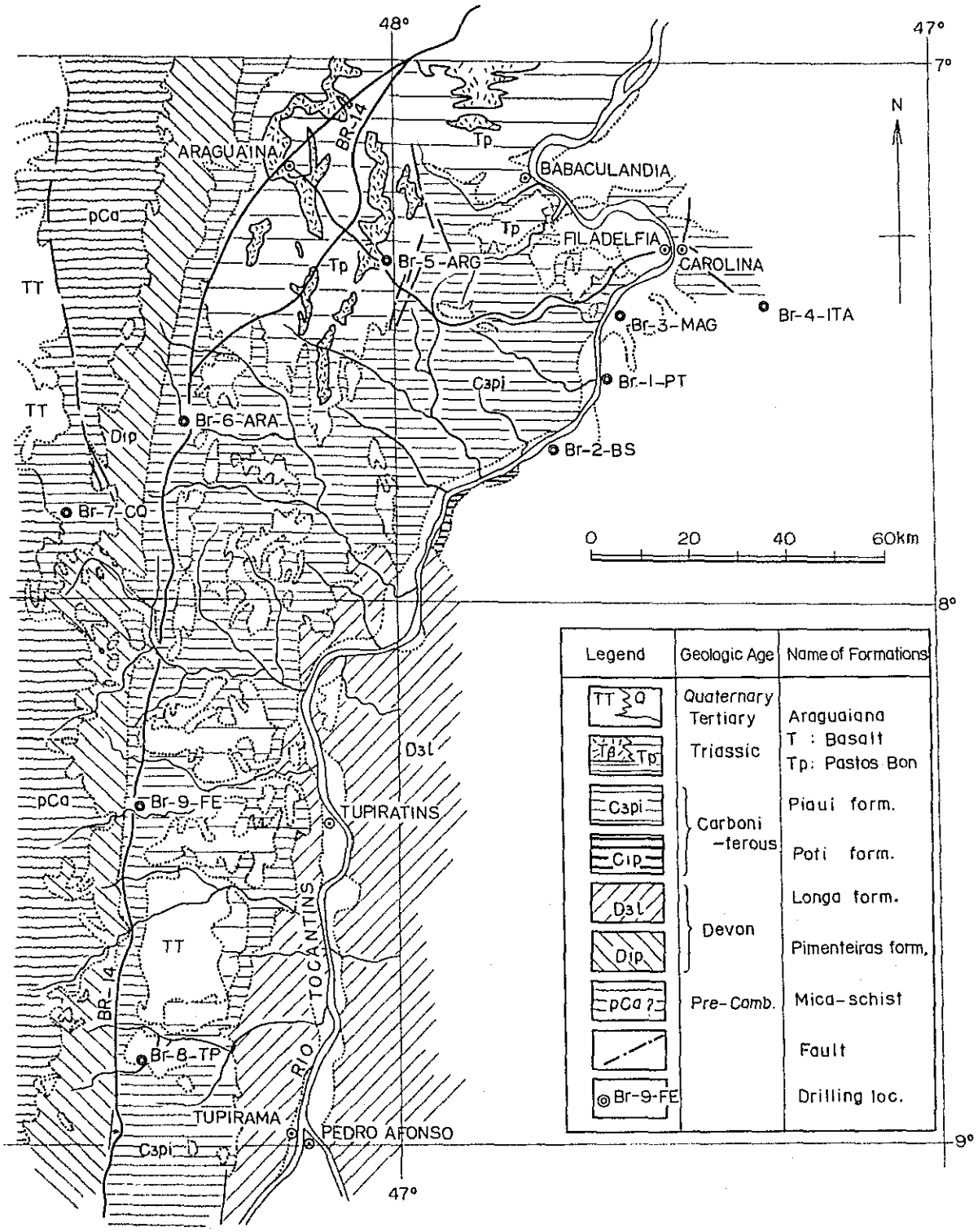


Fig. 9 Map showing geology and drilling points in the Rio Tocantins Coal Project area, Maranhão and Goiás

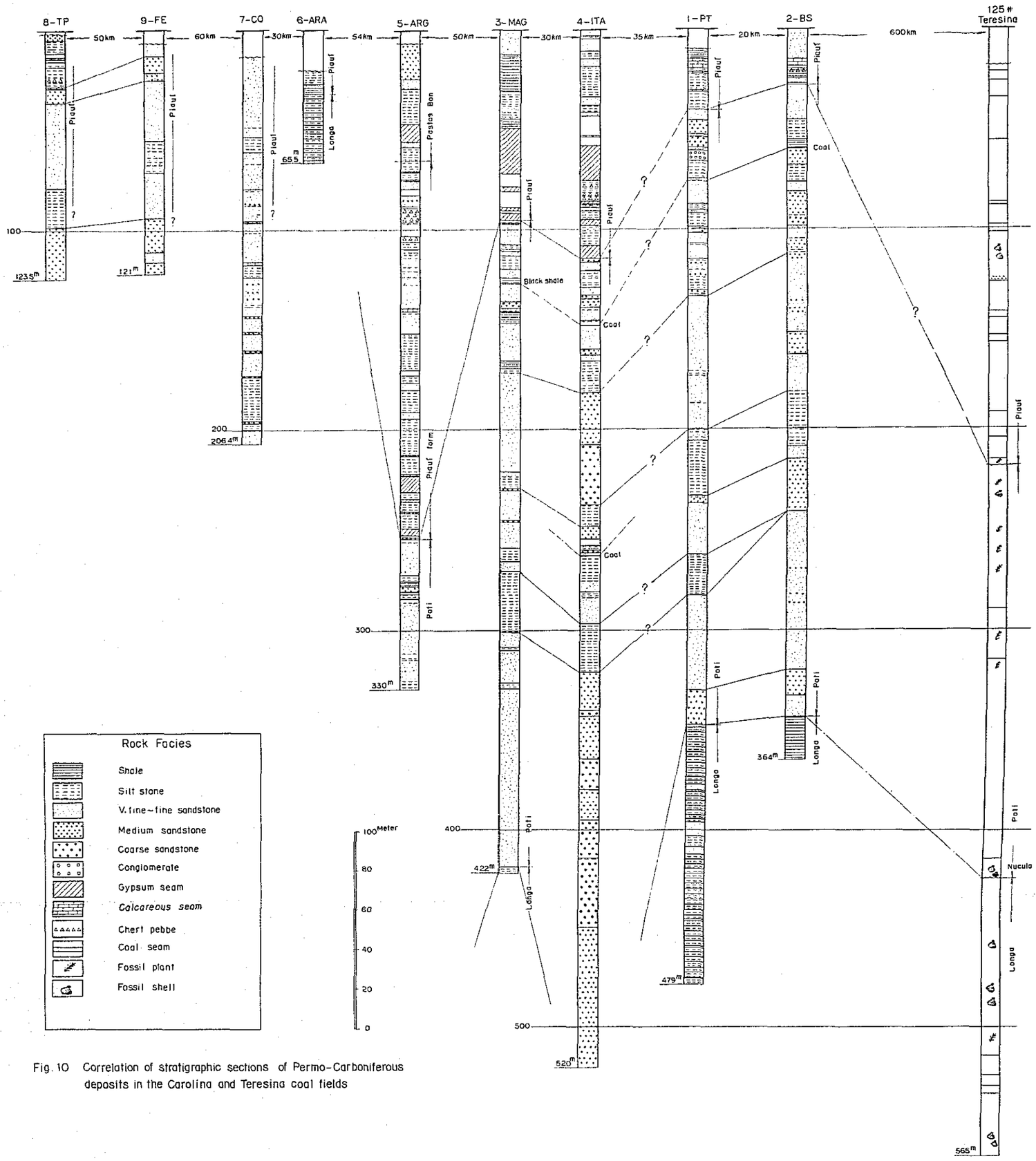


Fig. 10 Correlation of stratigraphic sections of Permo-Carboniferous deposits in the Carolina and Teresina coal fields

Parnaiba intercratonic basin in the northern part of Goiás State.

The geological map of this project is shown in Fig. 9. The drilling works were put into operation at eight locations in this prospecting area to confirm the existence of workable coal seams. The locations of the drilling holes are also indicated in Fig. 9, and the stratigraphic columnar sections at these drilling holes are arranged in Fig. 10.

In these columnar sections, the correlation of the sequences of strata in each drilling hole is set forth temporarily by putting the lower limit of the Piaui formation to the bottom of gypsum beds, and it is supposed that Piauí formation is composed mainly of aranaceous rock associated with more calcareous contents than that of the Poti formation.

It is noticed that there are some characteristics in the sedimentary feature in this coal field, as described hereunder.

1) The coal seams in the Poti formation were found only in the two drilling holes, which are located in the north-eastern extreme of the project area, that is, in the east side of the Tocantins River, and coal seams were not found in so far west side of the Tocantins River.

2) The sequence of strata of the drilling holes in the western bank of the Tocantins River shows that the thickness of Poti formation is very thin and in the western extreme of drilling holes (No. 4 drilling), the Piauí formation covers directly the underlying Devonian formation.

On the east bak of the Tocantins River, the thickness of the Poti formation is also variable and becomes thinner in the southern location than in the northern location.

3) The Devonian system which is overlain by the Carboniferous sediment shows a different distribution in each epoch of Devonian. The Longa formation, uppermost of Devonian, is distributed, accompanied with middle and lower Devonian formation, only on the eastern bank of the Tocantins River. But, on the western bank of the river, there is no upper and lower Devonian and only the Pimenteiras formation, the lowermost of Devonian is distributed unconformably under the Carboniferous sediment.

The lack of upper Devonian formation in the western margin suggests that the uplift movement of the basement continued there in the later Devonian period.

From the above mentioned fact, that the Piauí formation has more extended distribution than Poti formation and somet mes directly covers the Devonian formation, it could be supposed that the Piauí formation overlaps the underlying Potí rand Devonian formations.

The Poti formation which is distributed on the western bank of the Tocantins River shows the marginal facies in the sedimentary basin and is devoid of coal.

If there were some posibilities to find out coal in this basin, there might be another promising area far southeast of Carolina. The area to be proposed for a survey in the future will be in the ranges below.

Between	Latitude	07°30' and 10°00 S.
"	Longitude	47°00 and 48°00 W.

4. Teresina Coal Project

The Teresina Coal Project area in Piauí State is situated on the northeastern margin of the Parnaiba intercratonic basin, and located in east and south of Teresina.

The geologic map of this project is shown in Fig. 11, which is originated in the map prepared by PETROBRÁS.

The columnar section of "Piauí 125 drilling" in the report of DNPM is also arranged in Fig. 10, and the notes of formational subdivision and correlation of the columns between the Carolina and Teresina areas are also shown in this figure.

It is the popular view that the Piauí formation unconformably covers the Poti formation, but it seems to be plausible that the hiatus between the Poti and Piauí formation, to which Dr. Glycon de Paiva referred, would not be so great or be absent considering the evidence of unconformity.

1) The surface distribution of the Piauí and Poti formations are nearly parallel and the former seems to overlie conformably the latter.

2) The Piauí formation, intercalating of fossil shells in the muddy sediment and showing marine facies, might overlie comformably the Poti formation with only fossil plant and fragment, when the transgressing Piauí sea extended over the sedimentary area of the Poti formation.

3) In the columnar section of "Piauí 125 drilling", strata as deep as

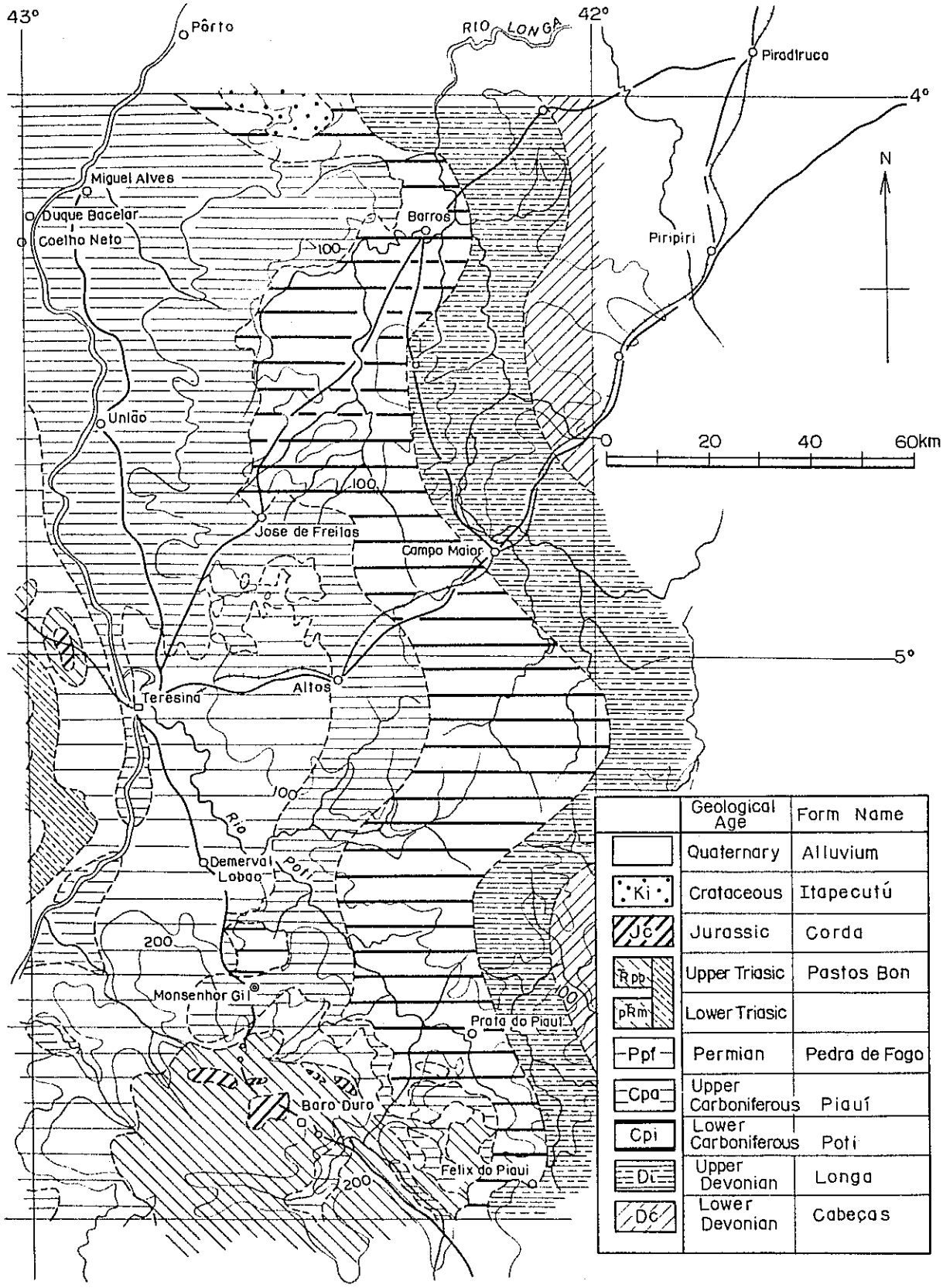


Fig. 11 Geological map of the Teresina Coal Project area, Piauí

415 m also intercalate the fossil shell and show the marine facies, but the geologic age of this formation, whether it belongs to Carboniferous or to Devonian, is not determined in the Glycon's report. It is plausible that this formation might correspond to the lower part of the Poti formation, although its facies are so different from those of the upper part.

The Team is of the opinion that the differences in the formation name, "Piauí" and "Poti", correspond to the differences in the facies whether they show marine or non-marine facies and that the Piauí and Poti facies show the interfingered two facies in the same sedimentary basin.

Therefore it could be supposed that there might be some promising areas where the Poti formation contains workable coal seams.

If there are some possibilities to find out coals in this project area, the ranges to be proposed for a survey will be the following areas in favorable order.

1) Between Latitude 04 30 and 05 00 S, Longitude 42 10 and 42 40 W.
2) " " 05 00 and 05 30 S, " 42 00 and 42 30 W.
3) " " 05 30 and 06 00 S, " 42 10 and 42 50 W.
4) " " 06 00 and 07 00 S, " 42 50 and 43 40 W.

V Conclusion

1. On the basic survey in the Northern Goiás State by the Japanese Government

(1) There are many possibilities of existence of nickel silicate ore deposits associated with ultramafic rocks, though prompt development of such type of ore deposits is not expected in a few years due to inconvenient haulage unless an ore deposit with large ore reserves is found out.

(2) However, due to the virtual lack of geological data, the first step to be taken in the basic survey is to prepare a photogeological map with a scale of 1 to 200,000 1 to 250,000 together with the airborne magnetic exploration and radioactive exploration for the purpose of clearing general geology, geological structure and the distribution of basic complexes.

Ground survey should be undertaken as the second step for further examination based on the results of the first step.

(3) It is recommended that the basic survey be carried out after analysing more informations given by the Japanese geologist dispatched to Brazil by the Japanese Government this year.

2. Possibility of finding coal in Parnaiba basin, especially in the Carolina and Teresina Project areas

(1) Carolina area

As the Piauí formation is distributed overlapping on the Poti and Devonian formations,the outcropping area of the Poti formation has less extension than the Piauí formation.

And there can not be found any coal seams in the areas far west from Carolina, because the Poti formation there shows the marginal facies in the Parnaiba sedimentary basin.

But there remains another promising area to be prospected far southwest from Carolina. The details of the ranges to be prospected were described in the foregoing chapter.

(2) Teresina area

This project area has the possibility of finding a coal deposit. The Poti formation represents the facies showing non-marine sedimentary environment, and it will be changeable in thickness and facies according to the sedimentary environment in the sedimentary basin. There may be some places

suitable for sedimentation of the economic coal bearing formation in this vast project area.

The details of the ranges to be prospected were described in the foregoing chapter.

(3) Possibility for development

It is impossible to make a plan for development of the coal field in the Parnaiba basin based on the data obtained up to the present, the first step is therefore to find out workable coal seams.

It is most important in the Carolina area to find out the economic coal deposits in the areas covered by the Piauí formation, and as to the Teresina area, the first step is to confirm the existence of coal field by geological survey followed by drillings. Core recovery of the drillings in the Carolina area was less than 30 per cent and drilling techniques have to be advanced, because the coal field is finally evaluated by drilling works.

The potentiality of existence of coal seems to be larger in the Teresina area than in the Carolina area, and the former is in better location for transportation than the latter.

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