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U. S. DEPARTMENT OF THE INTERIOR

RECONNAISSANCE FOR URANIUM IN THE
COAL OF SÃO PAULO, SANTA CATARINA,
AND RIO GRANDE DO SUL, BRAZIL

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This report is preliminary and has not been edited for con-
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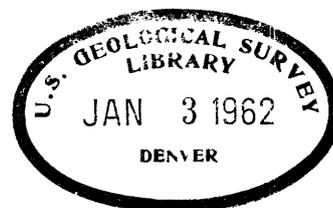


UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

RECONNAISSANCE FOR URANIUM IN THE COAL OF SÃO PAULO,
SANTA CATARINA, AND RIO GRANDE DO SUL, BRAZIL*

By

Donald D. Haynes, Charles T. Pierson
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*This report concerns work performed by the Brazilian National Nuclear Energy Commission and the United States Geological Survey (on behalf of the United States Atomic Energy Commission), and it is published with the permission of those agencies.

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RECONNAISSANCE FOR URANIUM IN THE COAL OF SÃO PAULO,
SANTA CATARINA, AND RIO GRANDE DO SUL, BRAZIL

ABSTRACT

Uranium-bearing coal and carbonaceous shale of the Rio Bonito formation of Pennsylvanian age have been found in the States of São Paulo, Santa Catarina, and Rio Grande do Sul, Brazil. The uranium oxide content of the samples collected in the State of São Paulo ranges from 0.001 percent to 0.082 percent. The samples collected in Santa Catarina averaged about 0.002 percent uranium oxide; those collected in Rio Grande do Sul, about 0.003 percent uranium oxide.

Since the field and laboratory investigations are still in their initial stages, only raw data on the radioactivity and uranium content of Brazilian coals are given in this report.

INTRODUCTION

Early in April 1956 a check for radioactive rocks in the sedimentary rock collection of the Departamento Nacional da Produção Mineral in Rio de Janeiro, Brazil, revealed some pieces of radioactive coal. Chemical analysis of the most radioactive pieces of coal from Nova Toquio (formerly Arthur Bernardes) in northeast Paraná (pl. I) indicated the presence of 0.03 percent uranium oxide.

Immediately thereafter, arrangements were made with certain government agencies of the States of Rio Grande do Sul and Paraná and with the DNPM organization in Santa Catarina to begin radioactivity investigations of the coal fields of those states. Complete cooperation was offered by all agencies consulted; the governments of the states greatly facilitated the investigations.

The highest grade of uranium-bearing coal was detected in northeast Paraná; therefore, the field work was concentrated in that region. Haynes and Pierson (1957) have reported on the results of investigations in Paraná.

The field work in Santa Catarina and Rio Grande do Sul was conducted during parts of May, June and July 1956. In mid-August the investigations were extended to the State of São Paulo.

These examinations of Brazilian coals were made by geologists of the official Brazil-United States group evaluating the uranium resources of Brazil. In São Paulo the investigations were carried out by Charles T. Pierson, Evaristo Ribeiro, Filho, and Henry Mau; in Santa Catarina, by Charles T. Pierson and Antonio C. Seára; and in Rio Grande do Sul, by

Charles T. Pierson and Evaristo Ribeiro, Filho, Carlos Pires Ferreira and Oswaldo Erichson de Oliveira made radioactivity and chemical analyses for uranium. Radiation instruments were maintained by M. Amoroso Anastacio and Geraldo Pedrozo. Almost all members of the joint group assisted in various phases of laboratory work.

This report concerns work performed by the Brazilian National Nuclear Energy Commission and the United States Geological Survey (on behalf of the United States Atomic Energy Commission), and it is published with the permission of these agencies.

Many individuals and organizations contributed to the work reported herein. Among these are the following: Dr. Artur Schneider of the Instituto Tecnológico de Rio Grande do Sul; Drs. Ney Pereira, Eurico Machado and Othon Castanho of the Departamento Autonomo do Carvão do Rio Grande do Sul; Dr. Nero Passos of the D. N. P. M. in Porto Alegre, Rio Grande do Sul; Drs. Victor Dequech and José Menescal Campos of Santa Catarina; and Dr. Viktor Leinz of the University of São Paulo.

GEOLOGY OF SOUTHERN BRAZIL COAL DEPOSITS

In southern Brazil coal is found in the Tubarão series of Pennsylvanian age (table 1), which is part of the Gondwanian sedimentary sequence that constitutes White's "Santa Catarina System" (1958). This series is exposed almost continuously from just north of the Minas Gerais-São Paulo border to the southern boundary of the State of Rio Grande do Sul (pl. I).

Tubarão series

The Tubarão series of the Paraná basin or geosyncline, which includes most of the area of the States of São Paulo, Paraná, Santa Catarina and Rio Grande do Sul, is comprised of a lower glacial sequence, the Itararé group, and an upper postglacial sequence, the Guatá group (table 1).

In the State of São Paulo the stratigraphic nomenclature of the Tubarão series has been completely revised from that used in Paraná, Santa Catarina and Rio Grande do Sul. The Itararé group, which is very thick in São Paulo, is no longer described as such by some geologists in that state, but rather is divided into four units which, from base to top, are the Itú, Capivari, Gramadinho and Tieté formations (see table 1). These geologists also have eliminated the term Guatá group and substituted therefore the Itapetinga formation, which is divided into three members, from base to top: Tupí, Tatuí and Taquaral. The lower two members probably correlate with the Rio Bonito formation and the upper member with the Palermo formation or "beds" (see below).

In the States of Paraná and Santa Catarina the Itararé group (Maack, 1947) is divided into the Palmira formation of continental-glacial origin and the Taíó formation of glacial-marine origin. Even though the existence of these two formations has been well established in Santa Catarina, their names have not yet been used in published geologic reports.

The Guatá group (Gordon, 1947) in Paraná and Santa Catarina has been divided into the Rio Bonito formation of coal-bearing sedimentary rocks and the Palermo formation of sedimentary rocks without coal seams.

In Rio Grande do Sul it is impossible to differentiate the units of the Tubarão series except locally; therefore, in that state it is mapped and described only as undivided Tubarão series.

The Itararé group thickens from the south to the north. In Rio Grande do Sul it can be recognized only locally, and may be as much as 100 meters thick. The thickness of the group in Santa Catarina ranges from 50 to 300 meters, and in Paraná from 380 to 470 meters. Its equivalents in São Paulo - the Itú, Capivari, Gramadinho and Tietê formations - may be as much as 1000 meters thick.

Itararé group

Palmirá formation. This formation consists of alternating glacio-lacustrine sediments, tillites, drifts, varvites and fluvio-glacial sediments and eolian deposits.

The Palmirá formation is as much as 370 meters thick in Paraná, the only state in which it can be easily differentiated from the overlying Taió formation.

Taió formation. This formation is comprised of fossiliferous sandstones, siltstones and conglomerates interbedded with clay and shale beds. In Paraná the Taió formation ranges in thickness from 65 to about 100 meters.

Guatá group

The type section of the Guatá group is in Santa Catarina where it is divided into the Rio Bonito and Palermo formations. The term "formation" is applied to the Palermo only in Santa Catarina; in Paraná and Rio Grande do Sul it is known as the Palermo "beds," denoting that the presence of the Palermo is recognized, but that it is not possible to differentiate it sufficiently from the underlying Rio Bonito formation to give it formational rank. In the State of São Paulo the Taquaral member of the Itapetinga formation probably is the equivalent of the Palermo formation or beds.

Rio Bonito formation. This formation consists of sandstones, siltstones, clay beds, and carbonaceous shales with fossil plants. In the Rio Bonito of Rio Grande do Sul there are three coal zones or beds; in the formation in Santa Catarina, five zones; and in Paraná and São Paulo, usually one zone, but in some places two. The Rio Bonito formation or its equivalents average about 125 meters in thickness in São Paulo, about 135 meters in Paraná, and about 150 meters in Santa Catarina and Rio Grande do Sul.

Palermo formation or "beds". The Palermo beds overlie the Rio Bonito formation conformably, and consist of gray and yellowish sandy shale interbedded with white, reddish and yellowish sandstones. Bands and nodules of

chert are abundant near the base of the Palermo beds in Paraná. The Palermo beds contain plants and fossil shells of fresh-water origin and fragments of silicified wood of the genus Dadoxylon. In most localities it is difficult to differentiate the Palermo beds from the Rio Bonito formation.

The Palermo beds range in thickness from 50 to 90 meters in Rio Grande do Sul and Paraná and from 50 to 100 meters in Santa Catarina. In São Paulo the probable equivalent to the Palermo beds, the Taquaral member of the Itapetinga formation, averages about 28 meters in thickness.

The Palermo beds are overlain by the bituminous black shales of the Irati group in the Passa Dois series of Permian age.

Coal deposits of south Brazil

In south Brazil the minable coal is obtained from the Rio Bonito formation of the Guata group. The coal ranges from subbituminous to semianthracite, but almost all the coal mined is of bituminous rank (table 2). The coal seams that are mined range from 30 to about 200 centimeters in thickness.

The semianthracite coal in the State of São Paulo is very thin, high in ash and sulfur content, and has only a very limited local use.

In Paraná the coal is extracted from a single coal zone that is usually divided into two coal seams, which are separated by a thin bed or split of sandstone or carbonaceous shale averaging about 60 centimeters in thickness. Above and below the sandstone or shale split the coal seams have a combined thickness ranging from 30 to 130 centimeters and averaging 75 centimeters. The coal in Paraná is mostly bituminous but ranges from subbituminous to semianthracite.

In Santa Catarina there are five coal zones or beds, starting with the lowest: Bonito, Ponte Alta, Irapuã, Barro Branco and Treviso. The Bonito bed was one of the first to be discovered in the state and is the bed in which the initial mining was undertaken in the southern part of Santa Catarina. This bed contains poor-quality coal which can no longer be mined economically. The Ponte Alta bed is of no economic importance. The Irapuã bed is second in economic importance after the Barro Branco bed; the former is widespread throughout the coal-bearing region of the state but is mined only locally. The Barro Branco bed is the most economically important one in the coal region, and is divided into two seams by a light-gray clay bed or split. It ranges in thickness from 120 to 200 centimeters and extends over a large area. The Treviso bed is very local in occurrence and is of no economic importance.

The coal mined in Santa Catarina is mostly of bituminous rank. The thickness of the coal mined from the Barro Branco bed averages only about 70 meters. In some places the coal zones are cut by diabase dikes and sills. A few faults cut the coal zones, but the displacements usually are no greater than one or two meters.

Table 2. Physical characteristics of the coals of south Brazil.

(Chart compiled from data published by Good, Abreu and Fraser (1949), parts I and II)

<u>Rank</u>	<u>Coking characteristics</u>	<u>Ash content (percent)</u>	<u>Sulfur content (percent)</u>	<u>Pyrite content</u>
<u>PARANA</u>				
Mostly bituminous but ranges from established subbituminous to subanthracite	Not clearly established	15 to 40	8 to 12	Very fine; large nodules common
<u>SANTA CATARINA</u>				
Bituminous (low-medium volatile)	Strong in Barro Branco bed	36 to 40	8 to 12	Heavy with inclusions making up as much as 25 percent of weight of mined material
<u>RIO GRANDE DO SUL</u>				
Subbituminous to bituminous	Noncoking	40 to 45	2 to 3	Lenses and continuous bands common; average content in coal 3 percent
<u>SÃO PAULO</u>				

There are two coal basins in the State of São Paulo--near the towns of Cerquillo and Tietê about 170 kilometers west of the city of São Paulo. These are thin seams of high-ash, high-sulfur, semianthracite coal that are not economically extractable. Coal is of limited local use.

<u>Hardness</u>	<u>Faulting</u>	<u>Assoc. igneous rocks</u>	<u>Economically recoverable minimum thick- ness (in cm.)</u>	<u>Best coal econom- ically minable after washing</u>		
				<u>% Ash</u>	<u>% S</u>	<u>Btu</u>
Hard to flaky and earthy (shaly)	Not common	Commonly cut by diabase dikes	40	16 to 18	4 to 6	11,300
In general strong, hard to cut	Few of any importance	Occasion- ally cut by dia- base dikes	60 to 80	16	1.5	—
Hard to flaky	Small faults common with displace- ments less than 3 meters	Commonly cut by diabase dikes	80	29	1.5	10,000

Three coal zones in Rio Grande do Sul largely contain subbituminous, noncoking coal. Where the coal zones are cut by diabase dikes and sills, the coal near the contact zone has been altered to semianthracite. The thickness of the coal that is being mined at present is about 150 centimeters. A few faults, with displacements usually of less than three meters, cut the coal zones in some areas.

RADIOACTIVITY INVESTIGATIONS

Field investigations for uraniferous coal and carbonaceous shale deposits in the States of São Paulo, Santa Catarina, and Rio Grande do Sul were conducted on a reconnaissance scale. The field checking for radioactivity was done with carborne scintillation equipment and hand scintillation or Geiger-Mueller counters. The results of coal investigations in the State of Paraná have been discussed by Haynes and Pierson (1957).

Only raw data on the radioactivity and uranium content of the coal samples are given in this report because the generally low radioactivity of the coal in Rio Grande do Sul and Santa Catarina did not justify detailed study. Although some of the coal and carbonaceous shale in São Paulo is moderately radioactive, the occurrences have not yet been studied in detail due to their inaccessibility and the fact that the more extensive and more radioactive deposits in Paraná offered a greater opportunity to study geologic distribution, mode of occurrence, and radioactive equilibrium conditions of uranium in coal.

São Paulo

During August 1956 the main coal localities of the State of São Paulo were checked for radioactivity. These included a coal occurrence near the town of Buri and four coal occurrences in the Rio Tietê basin (Barbosa and Almeida, 1949). Anomalous radioactivity was noted only at two localities near the town of Cerquillo in the Tietê basin; however, coal samples were collected from all localities visited (pl. I). The results of radiometric and chemical determinations on the samples are as follows (eU₃O₈ is radioactivity reported as equivalent uranium oxide):

Group A: Group A was collected from the Sitio dos Marcos coal mine 18 kilometers north of Buri.

- SPC 1A - Coal, 10 centimeters thick from an open cut; 0.006 percent eU₃O₈ (0.002 percent U₃O₈), 73.6 percent ash, and 0.003 percent U₃O₈ in ash.
- SPC 1B - Sandy clay under coal; 0.004 percent eU₃O₈ (0.001 percent U₃O₈), 97.6 percent ash, and 0.001 percent U₃O₈ in ash.
- SPC 1C - Clay and soil over coal; includes limonite concretions; 0.005 percent eU₃O₈ (0.001 percent U₃O₈), 94.2 percent ash, and 0.001 percent U₃O₈ in ash.

SPC 2 - Grab sample of coal from an outcrop; taken from same interval as samples SPC 1A, 1B and 1C but about 10 meters laterally; 0.005 percent eU₃O₈ (0.001 percent U₃O₈), 36.6 percent ash, and 0.001 percent U₃O₈ in ash.

Group B: Group B was collected from the Mato Seco coal mine, the southwesternmost of the two coal localities shown near Cerquilha on the map by Barbosa and Almeida (1949). The coal thickness at the mine ranges from 20 to 80 centimeters.

SPC 3A - Dark-gray, fine-grained, clayey sandstone below coal, 50-centimeter samples, base not exposed; 0.007 percent eU₃O₈ (0.001 percent U₃O₈), 93.0 percent ash, and 0.001 percent U₃O₈ in ash.

SPC 3B - Blocky, hard, lustrous coal 15 centimeters thick, at base of coal seam; 0.016 percent eU₃O₈ (0.014 percent U₃O₈), 11.5 percent ash, and 0.122 percent U₃O₈ in ash.

SPC 3C - Altered, soft, nonlustrous coal from upper 21 centimeters of coal seam; 0.011 percent eU₃O₈ (0.002 percent U₃O₈), 28.8 percent ash, and 0.007 percent U₃O₈ in ash.

SPC 3D - Alternating sandstone and claystone above coal, 30-centimeter-thick sample; 0.006 percent eU₃O₈ (0.001 percent U₃O₈), 94.5 percent ash, and 0.001 percent U₃O₈ in ash.

Group C: Samples collected from the northeasternmost of the two localities shown near Cerquilha on the Barbosa-Almeida map (1949).

SPC 4 - Coal from an outcrop in gully about 2 kilometers west of Cerquilha on the road to the Cimento Perú Company mine; chip sample from about the middle of the coal seam which is about 70 centimeters thick; coal is highly weathered; 0.016 percent eU₃O₈ (0.001 percent U₃O₈), 54.0 percent ash, and 0.001 percent U₃O₈ in ash.

SPC 5A - Washed coal from Cimento Perú Company stockpile about 2 kilometers west of Cerquilha; 0.005 percent eU₃O₈ (0.004 percent U₃O₈), 15.7 percent ash, and 0.011 percent U₃O₈ in ash.

SPC 5B - Unwashed carbonaceous shale from same stockpile as SPC 5A; 0.064 percent eU₃O₈ (0.082 percent U₃O₈), 55.4 percent ash, and 0.148 percent U₃O₈ in ash.

Group D: Samples collected from locality near former bridge crossing Rio Capivari on abandoned Tietê-Piracicaba road (Barbosa-Almeida map, 1949).

SPC 6 - Coal from outcrop at river level, exposed outcrop 30 centimeters thick, base is covered; 0.002 percent eU₃O₈ (0.003 percent U₃O₈), 75.2 percent ash, and 0.004 percent U₃O₈ in ash.

SPC 7 - Coal sample 30 centimeters thick from a coal seam in a slump block (?); 0.002 percent eU₃O₈ (0.007 percent U₃O₈), 77.5 percent ash, and 0.009 percent U₃O₈ in ash.

Group E: Collected from locality near Monte Mor (Barbosa-Almeida map, 1949).

SPC 8 - Coal taken from stockpile of mine which is now caved; 0.004 percent eU₃O₈ (0.001 percent U₃O₈), 14.0 percent ash, and 0.001 percent U₃O₈ in ash.

Santa Catarina

Radioactivity reconnaissance of coal in the State of Santa Catarina was done mainly in the vicinity of the town of Criciúma, but some mines near the towns of Lauro Mueller, Rio Acima and Siderópolis (pl. I) were also checked. The following mines in the Criciúma area were examined for radioactivity: Mina Onze of the Companhia Carbonífera Próspera, Boa Vista, São Marcos, Rio Bonito, Metropolitana, Colombo, Galo and Brasil. At Lauro Mueller the Guatá and Rio Bonito mines were checked; near Siderópolis the Montenegro, Malha Dois and Treviso mines were examined; and near Rio Acima the Cecília mine was checked. In addition, we checked the radioactivity of cores representing about 3500 meters of drilling in the Linha Batista area near Criciúma and of cores representing about 4000 meters of drilling near the towns of Sangão, Pio Correa and Rio Acima.

Radioactivity greater than three times background was noted only near the Montenegro and Malha Dois mines. Following are the results of analyses of samples collected from these mines:

Group A: Samples collected from the Montenegro mine.

SCC 1A - Sandstone from interbedded sandstone and shale, containing pyritic concretions, from lower Barro Branco beds about 5 or 10 meters below the coal in the nearby Montenegro mine; 0.008 percent eU₃O₈ (0.002 percent U₃O₈), 97.0 percent ash, and 0.002 percent U₃O₈ in ash.

SCC 1B - Shale from the above locality; 0.004 percent eU₃O₈ (0.001 percent U₃O₈), 85.5 percent ash, and 0.001 percent U₃O₈ in ash.

Group B: Samples from Malha Dois mine.

SCC 2A - 25 centimeters of alternating coal and carbonaceous shale from the Forro layer of the Barro Branco coal bed, immediately below clay of sample 2B; 0.005 percent eU_3O_8 (0.002 percent U_3O_8), 41.5 percent ash, and 0.005 percent U_3O_8 in ash.

SCC 2B - Clay from lower 33 centimeters of 1-meter-thick clay bed; 0.005 percent eU_3O_8 (0.002 percent U_3O_8), 91.6 percent ash, and 0.002 percent U_3O_8 in ash.

Rio Grande do Sul

In Rio Grande do Sul there are two coal basins, the São Jerônimo and the Bagé; the latter was not checked. Radioactivity investigations of coal and carbonaceous shale in the São Jerônimo basin consisted of testing the mines in the Leão and Butiá coal districts and checking drill cores from hole nos. PC-1, PN-1, PN-2, PN-5, PN-7, PN-8, PN-3RP, PN-4CH, PN-6CH, PN-9CH, F-1, F-172 and F-180 (all in the São Jerônimo basin).

No radioactivity greater than three times background was noted in any of the mines. Only three samples, all from Butiá, were taken. None of the drill cores, which represent most of the exploratory drilling in the São Jerônimo basin (Leão to Cachoeira do Sul), has radioactivity of more than twice background.

At Leão the Boa Vista and Recreio mines, as well as cinders from the coal-burning power plant, were checked with negative results. In Butiá only the Poço 4 mine was examined, and three samples from this mine gave the following results:

Group A:

RGC 1 - Chip-channel shale sample of 40 centimeters below a 10-centimeter-thick coal seam; 0.007 percent eU_3O_8 (0.002 percent U_3O_8), 79.1 percent ash, and 0.003 percent U_3O_8 in ash.

RGC 2 - Chip-channel coal sample of 10 centimeters; 0.008 percent eU_3O_8 (0.003 percent U_3O_8), 66.6 percent ash, and 0.005 percent U_3O_8 in ash.

RGC 3 - Chip sample of shale, 30 centimeters above the coal of RGC 2; 0.009 percent eU_3O_8 (0.003 percent U_3O_8), 84.3 percent ash, and 0.004 percent U_3O_8 in ash.

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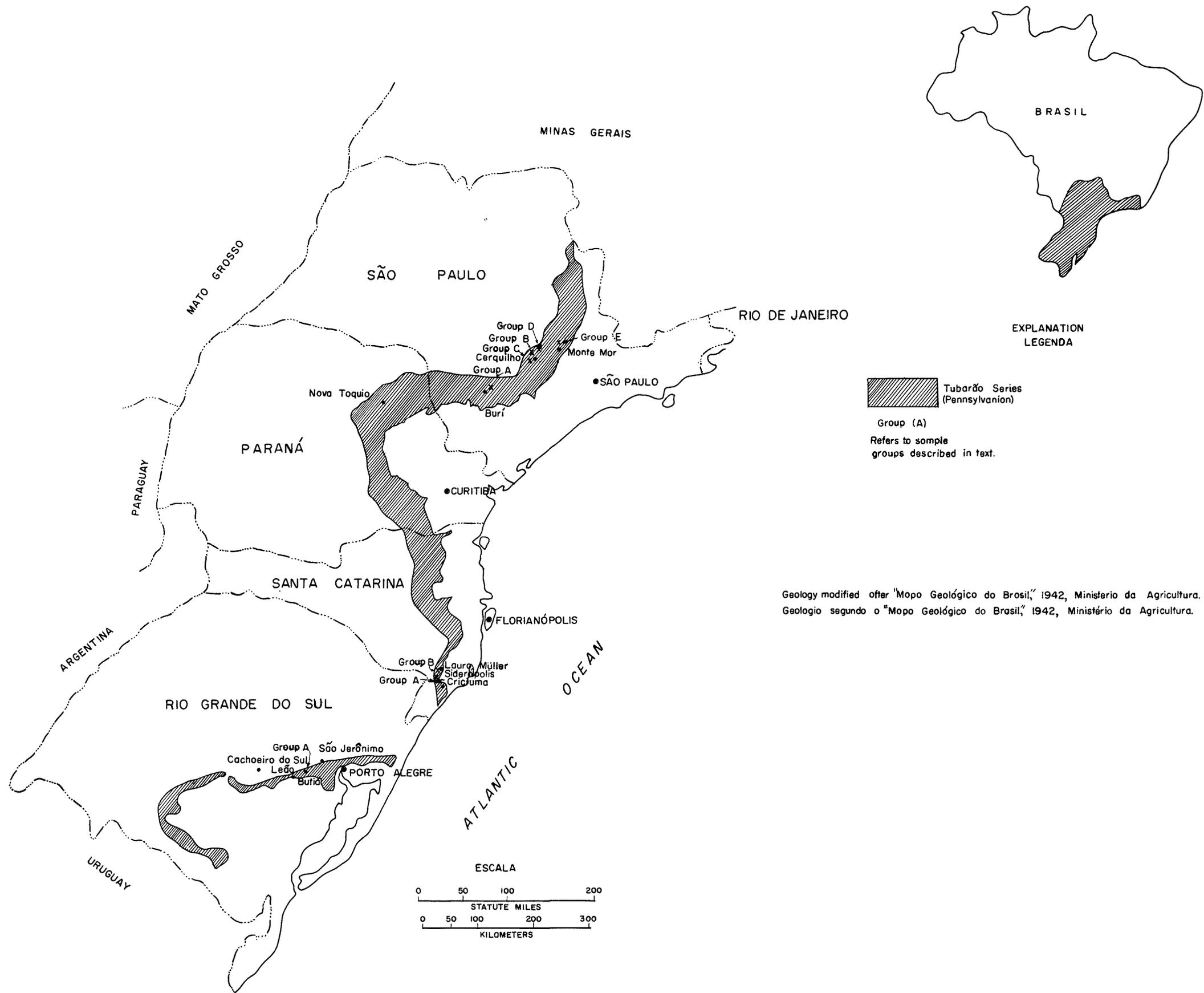


PLATE I. Sketch map of São Paulo, Paraná, Santa Catarina and Rio Grande do Sul showing distribution of Tubarão series and locations of sample groups