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RECONNAISSANCE FOR RADIOACTIVE MINERALS IN THE SOUTHERN PART OF BRAZIL*

By

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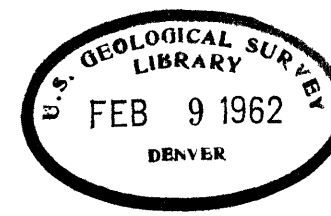

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RECONNAISSANCE FOR RADIOACTIVE MINERALS IN THE SOUTHERN PART OF BRAZIL

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ABSTRACT

During 1954-1956 a reconnaissance for radioactive minerals was made with carborne, airborne and handborne scintillation equipment in the southern Brazilian states of Rio de Janeiro, São Paulo, Paraná, Santa Catarina and Rio Grande do Sul. During the traverse covering more than 5,000 kilometers the authors checked the radioactivity of Precambrian igneous and metamorphic rocks, Paleozoic, Mesozoic and Cenozoic sedimentary rocks, and Mesozoic alkalic intrusive and basaltic extrusive rocks.

The 22 samples collected contained from 0.003 to 0.029 percent equivalent uranium oxide and from 0.10 to 0.91 percent equivalent thorium; two samples were taken from radioactive pegmatites for mineralogic studies. None of the localities is at present a commercial source of uranium or thorium; however, additional work should be done near the alkalic stock at Lages in the State of Santa Catarina and at the Passo das Tropas fossil plant locality near Santa Maria in the state of Rio Grande do Sul. Near Lages highly altered alkalic rock from a dike contained 0.026 percent uranium oxide. At Passo das Tropas highly altered, limonite-impregnated sandstone from the Rio do Rasto group of sedimentary rocks contained 0.029 percent uranium oxide.

INTRODUCTION

This report describes the results of reconnaissance for radioactivity of rocks, exclusive of coal, in the States of Rio de Janeiro, São Paulo, Paraná, Santa Catarina and Rio Grande do Sul during the years 1954 through 1956. Reports on reconnaissance and detailed studies of uraniferous coal are being prepared for publication.

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.

Most of the members of the official Brazil-United States group contributed to the present study. Max G. White, who started reconnaissance work in Brazil in August 1952, studied the Niteroi pegmatite in 1954; Helmuth Wedow, accompanied by Geraldo Melcher of the Departamento Nacional do Produção Mineral, made a reconnaissance in the Ribeira River Valley in 1955. In 1956 the following work was done: H. Wedow, C. Pierson and H. Mau, State of Rio de Janeiro; C. Pierson, E. Ribeiro and H. Mau, State of São Paulo; D. Haynes, H. Wedow, L. Zingoni and A. Sobanski, State of Paraná; C. Pierson and A. Seára, State of Santa Catarina; and C. Pierson and E. Ribeiro, State of Rio Grande do Sul.

Laboratory analyses for equivalent and chemical uranium were made in the Rio de Janeiro laboratories of the Departamento Nacional do Produção Mineral by Carlos Pires Ferreira and Oswaldo Erichsen de Oliveira. X-ray mineralogic studies were made by Elysiário Távora of the D.N.P.M. and by Betsy Levin of the U. S. Geological Survey, Washington, D. C. Electronics specialists M. Amorosco Anastacio and Geraldo Pedrozo aided both in the laboratory and in the field.

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GEOLOGY

The following summary of the general geology of the southern states of Brazil has been adapted largely from a paper by Oliveira (1956), and papers by Gordon (1947), Maack (1947), and Oliveira and Leonardos (1943).

The geologic map (fig. 1), adapted from the 1942 geologic map of Brazil, has been generalized into the following units: Precambrian rocks; Paleozoic and Mesozoic sedimentary rocks; Triassic basalt flows; Jurassic (?) alkalic intrusive rocks; Tertiary sedimentary rocks; and Quaternary deposits.

Precambrian rocks

The Precambrian rocks of southern Brazil are shown undivided on figure 1. Included also are several small bodies of intrusive rock whose age is not known more closely than pre-Devonian.

The Precambrian rocks comprise a large number of rock types and units, usually of complex structure. Among the types tested during the reconnaissance were granitic rocks, granitic gneiss, schist, pegmatite and marble.

Paleozoic and Mesozoic sedimentary rocks

Only those Paleozoic and Mesozoic sedimentary rock units checked during the reconnaissance will be described in this report. These sedimentary rocks,

which are for the most part of continental origin, are in ascending order: (1) the Seival conglomerate of unknown age; (2) the Campos Gerais series of Early Devonian age; (3) the Tubarão series of Pennsylvanian age; (4) the Passa Dois series of Permian age; (5) the São Bento series of Triassic and Jurassic age; and (6) the Baurú series of Cretaceous age.

The Seival conglomerate occurs only in Rio Grande do Sul, and has been described by Leinz, Barbosa and Teixeira (1941). The formation, which is composed largely of andesitic pebbles and cobbles, overlies the Camaquã series of Silurian age, but its relation to the overlying Tubarão series is not clear.

In Paraná the Campos Gerais series of Early Devonian age (Maack, 1947) consists mainly of marine sandstones and shales. The series lies on an erosional unconformity on metamorphic and igneous rocks of probable Precambrian age.

In Paraná and Santa Catarina the Tubarão series of Pennsylvanian age is divided into a lower, glacial group, the Itararé, and into an upper, post-glacial group, the Guatá. The Itararé group has been subdivided only locally, but the Guatá group is divided into the underlying, coal-bearing Rio Bonito formation, and the overlying Palermo shale. In São Paulo and Rio Grande do Sul it is difficult to separate the Itararé and Guatá groups.

The Passa Dois series includes all the Permian formations of southern Brazil. It is divided into the older Estrada Nova and younger Rio do Rasto groups. The Estrada Nova group consists of claystones, siltstones and limestones, with the bituminous shales of the Irati formation at the base. The Rio do Rasto beds are chiefly sandstones but include some silt, shale and conglomerate beds.

The São Bento series of Triassic and Jurassic age comprises, in ascending order, the Santa Maria formation, the Botucatú sandstone and the Serra Geral formation. The Santa Maria formation, found only in Rio Grande do Sul, consists mainly of sandstones and argillaceous shales. The Botucatú sandstone comprises the thick eolian sandstone below the lowest lava flow of the Serra Geral formation. In São Paulo and Paraná a thin basal layer, probably of fluvial origin, is named the Piramboia sandstone. The Serra Geral formation is comprised of basaltic flows ranging in total thickness from 400 to 800 meters. In São Paulo, northern Paraná and Rio Grande do Sul the lava flows are separated locally by lenticular beds of crossbedded eolian sandstone.

The Baurú series of Cretaceous age, which is found in São Paulo, consists of continental deposits of sandstone and some clay, shale, conglomerate and arkose. A conglomerate containing basalt pebbles and boulders of Precambrian rocks is infrequently found at the base. These formations almost always rest on basalt.

Tertiary sedimentary rocks

The principal Tertiary sediments of the southern states of Brazil are those of the Paraiba River Valley in São Paulo and Rio de Janeiro. These sediments are well exposed along the Rio de Janeiro-São Paulo highway and and consist mainly of clays, shales and sandstones. The deposits are probably of Pliocene age.

Quaternary deposits

The Quaternary deposits of the southern states of Brazil consist mainly of alluvium and thick soil. Sandy deposits along the coasts are found in Rio Grande do Sul, and small deposits of peat (turfa) are known in the States of São Paulo and Rio de Janeiro.

Alkalic intrusive rocks

Alkalic intrusive rocks of Jurassic (?) age occur at numerous localities in southern Brazil. Among the most important occurrences are the following: (1) State of Rio de Janeiro, Itatiáia and Tinguá massifs, and the rocks of Cabo Frio Island; (2) State of São Paulo, São Sebastião Island, Ipanema, and Jacupiranga; and (3) State of Santa Catarina, Lages and Anitopolis.

The alkalic rocks occur as large intrusive massifs and also as dikes and sills. Some of the rocks contain notable concentrations of titaniferous magnetite; and the Ipanema intrusive, described by Leinz (1940), contains pneumatolytic-hydrothermal deposits of apatite.

RADIOACTIVITY RECONNAISSANCE

Reconnaissance radioactivity studies in southern Brazil were made with carborne, airborne or handborne scintillation counters. The museum collections of various state and federal agencies provided the preliminary radioactivity data used in guiding the field studies.

Background radioactivity readings over alluvium during carborne traverses averaged about 0.003 milliroentgens per hour (mr/hr) and about 50 counts per second, respectively, for the two instruments used. Readings of twice or more background on the carborne instrument were tested on foot using the hand scintillation counters. Samples were taken where spot readings were three or more times greater than the background.

State of Rio de Janeiro

Field work in the State of Rio de Janeiro consisted of testing: (1) Precambrian rocks in the vicinity of the cities of Rio de Janeiro and Niteroi; (2) the Precambrian rocks and Tertiary sedimentary rocks along the Rio de Janeiro-São Paulo highway; (3) part of the alkalic stock near Itatiáia; and (4) peat in the vicinity of the town of Resende.

Uraninite is associated with a pegmatite near Niteroi, and limonite and manganese oxide from a fracture in alkalic rock near Itatiáia is radioactive. The Precambrian rocks and the Tertiary sediments have a moderately strong mass effect, but no significant concentrations of radioactive minerals were found. Parts of the alkalic stock showed moderate mass radioactivity, but the peat registered very low radioactivity. Results of analyses of samples from localities 1 through 4 are shown in table 1. Localities are shown in figure 1.

At Niteroi (loc. 1) uraninite occurs in minor amounts in a garnet-bearing felsic pegmatite containing small amounts of zircon, green xenotime, and magnetite. The uraninite is associated mainly with the biotite from a pocket in the pegmatite. Zippeite coats uraninite grains and biotite crystals.

Samples of rock (locs. 2 and 4) from the alkalic stock near Itatiáia contained as much as 0.009 percent equivalent uranium oxide (eU_3O_8) but only 0.002 percent uranium oxide (U_3O_8). A sample of mixed limonite and manganese oxide (loc. 3) from a fracture in foyaite contained 0.054 percent eU_3O_8 but only 0.002 percent U_3O_8. Nearby rock from a dike, as well as material from a pegmatite, contained only 0.002 percent eU_3O_8.

Table 1. Analysis of anomalously radioactive samples from the State of Rio de Janeiro.

Locality no.	Sample no.	eU_3O_8 (percent)	U_3O_8 (percent)	Description and location of samples
1	RJ-36	-	-	Uraninite associated with biotite from pocket in pegmatite, Pendotiba quarry, Niteroi; zippeite coats uraninite grains and biotite crystals.
2	RJ-66	0.006	0.002	Highly altered alkalic rock from road cut about 5 km. north of Itatiáia.
3	RJ-67	0.054	0.002	Limonite and manganese oxide from fracture in alkalic rock; from road cut about 7 km. north of Itatiáia.
4	RJ-68	0.009	0.002	Fairly fresh, coarse-grained alkalic rock; from locality of Sample no. 3.

State of São Paulo

In the State of São Paulo road checks for radioactivity, using a car-borne instrument, were made along the São Paulo-Rio de Janeiro highway and along various roads in the eastern part of the state (fig. 1); tests with hand scintillation counters were made in the Ribeira River Valley region near the state border of São Paulo and Paraná. The work covered various rock types of Precambrian age, sedimentary rocks of Paleozoic and Mesozoic age, basalt flows of Triassic age, alkalic rocks of Jurassic age, sedimentary rocks of Tertiary age and alluvium of Quaternary age. Results of analyses of samples from the São Paulo localities nos. 5 through 11 are shown in table 2.

Precambrian rocks were tested in the Ribeira region, in the vicinities of the towns of Ipanema, Jundiaí and Perus, and in road cuts in numerous places. Although the Precambrian rocks generally gave fairly high mass readings, frequent spot checks failed to locate any significant concentrations of radioactive material except in the Ribeira region and at the previously known locality near Perus.

In the Ribeira region a brief reconnaissance of the Serra do Itapirapuã was made in 1955 by Helmuth Wedow of the U. S. Geological Survey and Geraldo Melcher of the Departamento Nacional do Produção Mineral (Melcher and Wedow, 1955, written communication) as a followup of information from the Instituto Geografico e Geológico of the State of São Paulo that certain lead-bearing samples from this region were radioactive.

The region studied (loc. 11) is west of the town of Ribeira. The area of the most important radioactivity covers about two square kilometers. The rocks of the region are of Precambrian age and consist of metasedimentary rocks of the São Roque series and of granite and quartz syenite which cut the metasedimentary rocks. The lead deposits are found in calcareous parts of the metasedimentary rocks. Samples from the lead occurrences contained as much as 0.91 percent equivalent thorium oxide ($eThO_2$). One sample contained 0.67 percent ThO_2 and 9.1 percent rare-earth elements. The thorium mineral, which is extremely fine grained, has not been identified.

Near Ipanema Precambrian limestone intruded by an alkalic stock showed very low radioactivity.

At the Inhandjara tungsten mine near Jundiaí wolframite-quartz veins in granite and gneiss had very low radioactivity. Mill concentrates (table, jig and electromagnet) were very low in radioactivity.

In the Perus district secondary uranium minerals occur in and near pegmatites of pre-Devonian age (Knecht, 1936; Henry Mau, oral communication). The pegmatites, which occur mainly in schist but sometimes cut tourmaline granite, are quarried for kaolin and feldspar. At the Peccicacco quarry (loc. 8) a mixture of meta-autunite and torbernite coats fractures in tourmaline granite and pegmatite.

Table 2. Analysis of anomalously radioactive samples from the State of São Paulo.

Locality no.	Sample no.	eU_3O_8 (percent)	U_3O_8 (percent)	Description and location of samples
5	SP-82	0.10 ($eThO_2$)	-	Quaternary gravel from quarry near Tremembé; radioactivity due mainly to monazite.
6	SP-64	0.011	0.003	Tertiary sedimentary rock composed largely of reworked granite; from road cut near town of Bairro Germana, about 10 km. southeast of Caçapava.
7	SP-65	0.004	0.003	Highly weathered granitic gneiss; from road cut about 1 km. southeast of Sample no. 6.
8	-	-	-	Meta-autunite and torbernite as coatings of fractures in tourmaline granite and tourmaline granite pegmatite; Peccicacco Quarry near Perus.
9	SP-81	0.016	0.005	Red argillaceous shale of the Tubarão series containing traces of zircon, monazite and rutile; from road cut 8 km. south of Rio das Pedras.
10	SP-78	0.026	0.008	Red limey shale of the Estrada Nova group; contains traces of zircon, magnetite and monazite; from road cut about 2 km. west of Angatuba.
11	RR-6	0.91 ($eThO_2$)	-	Yellow, altered limestone from the Ribeira River Valley region.

Testing of sedimentary rocks of Paleozoic and Mesozoic ages included mainly road traverses of the Tubarão, Passa Dois, São Bento and Baurú series. However, detailed studies with hand scintillation counters were made of the asphaltic Piramboia sandstone near Angatuba and at the quarry of the Asfalto Paulista Betumita, S. A. near Anhembí; of the asphaltic Irati formation at the Assistencia quarry near Rio Claro; and of phosphatic material in the Corumbataí formation (Mendes, 1952) of the Estrada Nova group near Rio Claro. Significant radioactivity was found at only two localities: (1) shale of the Tubarão series near Rio das Pedras; and (2) shale of the Estrada Nova group near Angatuba. Red argillaceous shale of the Tubarão series from a road cut near Rio das Pedras (loc. 9) contained 0.016 percent eU_3O_8 and 0.005 percent U_3O_8. Red limey shale of the Estrada Nova group from a road cut near Angatuba (loc. 10) contained 0.026 percent eU_3O_8 and 0.008 percent U_3O_8. Both of these occurrences are small, and the radioactivity probably is caused chiefly by small amounts of monazite.

Triassic basalt of the Serra Geral formation was tested at several places including a quarry near Angatuba, and along the roads in the vicinities of Piracicaba, Rio Claro and São Carlos. The radioactivity was consistently low, including those localities where feeder dikes were tested.

Alkalic intrusive rocks of Jurassic (?) age were checked at Ipanema (Leinz, 1940; Moraes, 1938). Neither the alkalic rock of the intrusive, the apatite-magnetite deposits in the alkalic rock, nor the Precambrian limestone in a quarry at the border of the intrusive were anomalously radioactive.

Tertiary sedimentary rocks were tested along the highway from São Paulo to Rio de Janeiro. In general, their radioactivity mass effect is fairly high. A sample (loc. 6), taken from one of the more radioactive localities, contained 0.011 percent eU_3O_8 but only 0.003 percent U_3O_8. A sample of nearby Precambrian granitic gneiss (loc. 7), from which the sediments were derived, contained 0.004 percent eU_3O_8 and 0.003 percent U_3O_8.

Alluvium of Quaternary age was tested only incidentally during the work, and generally was not found to be radioactive. However, Quaternary gravel from a quarry near Tremembé in the Paraiba Valley (loc. 5) contained 0.1 percent $eThO_2$. The radioactivity is caused by monazite (Ribeiro, 1956, written communication).

State of Paraná

In the State of Paraná reconnaissance for radioactive minerals consisted of road traverses with hand scintillation counters, airborne traverses with a scintillation counter mounted in a helicopter, and ground traverses of smaller areas.

A road traverse (fig. 1), using a scintillation counter, was made in southeast Paraná starting in Curitiba and passing through the cities of Irati, Mallet and Lapa. A road traverse was made also from Mallet westward for a distance of about 18 kilometers.

Airborne work, using a scintillation counter mounted in a helicopter, consisted of traversing the various rock units in northeast Paraná, following highways, rivers and railroads (fig. 1).

Tests for radioactivity were made near Timbotuva and Ferraria about 20 kilometers west of Curitiba. The localities, which are in pre-Devonian rock, were an old gold mine at Timbotuva and kaolin deposits south of Ferraria.

The road traverse from Curitiba and return crossed rocks ranging in age from Precambrian to Quaternary, but only rocks of the Iratí and Poço Preto formations of Permian age and the Piramboia sandstone of Triassic age were found to be anomalously radioactive. Results of analyses of samples are shown in table 3.

Table 3. Analysis of anomalously radioactive samples from the State of Paraná.

Locality no.	Sample no.	eU_3O_8 (percent)	U_3O_8 (percent)	Description and location of samples
12	PnC-17	0.005	0.002	Two-meter channel sample of bituminous black shale of Iratí formation; from outcrop behind railroad station in Engº Gutierrez.
13	PnC-18	0.006	0.002	Sample from Poço Preto formation just below Poço Preto-Piramboia contact. Collected about 8 km. west of Mallet.
14	PnC-20	0.003	<0.002	Sample from Piramboia facies at base of Botucatú sandstone. Collected from outcrop west of bridge crossing Rio Claro on road to Pinaré.
15	PnC-21	0.005	<0.002	Sample from Piramboia facies at base of Botucatú sandstone. Collected from outcrop west of bridge crossing Rio Claro on road connecting Mallet and Pinaré.
16	PnC-23	0.005	0.002	Sample of bituminous black shale from Iratí formation. Collected from road cut 0.4 km. south of bridge crossing Rio Iguaçu at São Mateus do Sul.
17	PnC-24	0.009	0.002	Sample from kaolin mine about 2 km. south of Ferraria.

The first significant anomaly discovered after leaving Curitiba was in the bituminous black shale of the Iratí formation at Engº Gutierrez, south of the city of Iratí (loc. 12). A two-meter channel sample was taken from an outcrop behind the railroad station. The outcrop was radioactive throughout the exposed thickness of two meters. Laterally, the radioactivity seemed to remain constant with that from the sample location, the outcrop being radioactive for a distance of about 150 meters before becoming covered.

Anomalous radioactivity was detected in the Poço Preto formation about eight kilometers northwest of Mallet on the road to Pinaré (loc. 13). The Poço Preto formation consists of red and gray siltstone and shale interbedded with red sandstone. The red siltstone and shale beds seem to be the most radioactive, averaging about three times the background.

Samples from localities 14 and 15 were collected from the Piramboia sandstone facies at the base of the Botucatú sandstone of the São Bento series of Triassic age. At locality 14 a sample was collected just above the Poço Preto-Piramboia contact; at locality 15 a sample was collected below what seemed to be the Piramboia-Botucatú contact. Both samples were taken from a road cut in which the rock is completely altered; the sandstone is so completely weathered that the cementing material has been removed.

On the traverse from Mallet to Curitiba anomalies were detected only in the bituminous black shales of the Iratí formation. A sample was taken from a road cut about 0.4 of a kilometer south of the bridge crossing the Rio Iguaçu at São Mateus do Sul (loc. 16).

Several gold-bearing quartz veins were checked at the old gold mine at Timbotuva, but no radioactivity was noted.

The kaolin deposits south of Ferraria (loc. 17) were checked, and a sample was collected from one of the more radioactive deposits. Samarskite and euxenite have been found in the deposits, but neither mineral was visible in the sample collected.

Detailed laboratory work was not done on any of the samples taken during the reconnaissance because of the small amount of uranium present.

An airborne traverse in the vicinity of Piraí do Sul in northeast Paraná covered parts of the Campos Gerais series, Itararé group, and pre-Devonian rocks, including the Castro quartz porphyry and Iapó formation. No anomalies were found.

State of Santa Catarina

Reconnaissance for radioactive minerals in the State of Santa Catarina consisted of road traverses with carborne scintillation equipment in the eastern part of the state (fig. 1). During this traverse part of northeastern Rio Grande do Sul was checked. In Santa Catarina a representative part of all or nearly all the rock units of the state including Precambrian

rocks, sedimentary rocks of Paleozoic and Mesozoic age, basalt flows of Triassic age, and alkaline intrusive rocks of Jurassic (?) age were tested.

During the work several minor radioactivity anomalies were found, but only two were sampled (table 4). One of the samples was taken from near the alkalic stock near Lages (Paiva, 1933) and the other from sandstone of the Rio Bonito formation near Criciuma. Among the localities not sampled at which small anomalies were noted are a Precambrian dioritic gneiss on the highway between Tubarão and Florianopolis, and pegmatitic material in Precambrian granite on the highway between Florianopolis and Lages.

Table 4. Analysis of anomalously radioactive samples from the State of Santa Catarina.

Locality no.	Sample no.	eU_3O_8 (percent)	U_3O_8 (percent)	Description and location of samples
18	SC-61	0.021	0.026	Highly altered alkalic rock from dike in the Rio do Rasto group; from road cut about 20 km. east of Lages on the Lages-Florianopolis highway.
19	SCC-1A	0.008	0.002	Sandstone from interstratified sandstone and shale with pyritic concretions, Rio Bonito formation; from road cut between Criciuma and Sideropolis.

The sample from the Lages region (loc. 18) consists of highly altered alkalic rock from a dike in the Rio do Rasto formation. The sample contained 0.021 percent eU_3O_8 and 0.026 percent U_3O_8. The uranium is associated with iron oxide, but no uranium mineral could be identified by X ray.

The sample of sandstone from near Criciuma (loc. 19) came from interstratified sandstone and shale containing pyritic concretions. The beds are the lower Barro Branco beds of the Rio Bonito formation of the Tubarão series; the sample was collected about 7 meters below a coal bed (which is worked in the nearby Montenegro mine). The sandstone contained 0.008 percent eU_3O_8 and 0.002 percent U_3O_8.

State of Rio Grande do Sul

Work in the State of Rio Grande do Sul consisted of a road traverse with scintillation counters. Rocks examined included granite, pegmatite, schist and marble of Precambrian age; sedimentary rocks of Paleozoic and Mesozoic age; and basalt of Mesozoic age. Several mines and quarries were tested (table 5).

Table 5. Analysis of anomalously radioactive samples from the State of Rio Grande do Sul.

Locality no.	Sample no.	eU_3O_8 (percent)	U_3O_8 (percent)	Description and location of samples
20	RS-56	0.006	0.002	Altered basalt of the Serra Geral formation; from road cut about 10 km. north of Santa Maria on the road to Julio de Castilhos.
21	RS-57	0.026	0.029	Highly altered, limonite-impregnated sandstone from the Rio do Rasto group; uranium is associated with iron oxide; from road cut at Passo das Tropas fossil-plant locality, about 8 km. south of Santa Maria on the road to São Sepé.
22	RS-58	0.008	0.002	Precambrian biotite schist associated with marble and pegmatite; only the schist is radioactive; from Dagoberto quarry, about 12 km. northeast of Caçapava.
23	RS-59	0.003	0.002	Andesitic rock from the Seival conglomerate; from road cut about 15 km. south of Caçapava on road to Lavras.
24	RS-60	0.004	0.003	Coarse-grained granite from stock pile of Precambrian granitic and pegmatitic material; Mina da Sanga Negra, about 35 km. south of Encruzilhada.

Small radioactivity anomalies were found in Triassic basalt of the Serra Geral formation near Santa Maria, in the Rio do Rasto group at Passo das Tropas fossil-plant locality near Santa Maria, in the andesitic Seival conglomerate of unknown age near Caçapava and Encruzilhada. No anomalous radioactivity was found in the Santa Maria formation at the Alemoa and São José vertebrate-fossil localities near Santa Maria, at the Andradas and Primavera copper mines in Precambrian schist near Caçapava, nor in Precambrian marble from quarries near Caçapava and Encruzilhada.

Altered Triassic basalt north of Santa Maria (loc. 20) showed low anomalous radioactivity within an area of road-cut surface of a few square meters. A sample contained 0.006 percent eU_3O_8 and 0.002 percent U_3O_8.

Highly altered, buff-colored, limonite-impregnated sandstone of the Rio do Rasto group from the Passo das Tropas fossil-plant locality (loc. 21) south of Santa Maria (Gordon and Brown, 1952) contained 0.026 percent eU_3O_8 and 0.029 percent U_3O_8. The area of radioactivity is less than a meter on each side and is flat lying. Exposures are poor and trenching would be needed to determine if there is any structural control of uranium deposition, as well as to ascertain the stratigraphic relations of the buff-colored sandstone to the normal red siltstone of the Rio do Rasto formation.

Andesitic rock from the Seival conglomerate of unknown age (Leinz, Barbosa and Teixeira, 1941) exposed in a road cut south of Caçapava (loc. 23) is slightly radioactive throughout a length of about 0.35 kilometer in a road cut. A sample from this zone contained only 0.003 percent eU_3O_8 and 0.002 percent U_3O_8.

Small radioactivity anomalies were noted in Precambrian granite and schist at several localities near Caçapava and Encruzilhada. Near Caçapava radioactivity was noted at the Dagoberto quarry northeast of the town, and numerous anomalies were detected at the road cuts in granite and schist between Encruzilhada and Mina Sanga. A sample of biotite schist from the Dagoberto quarry (loc. 22) contained 0.008 percent eU_3O_8 and 0.062 percent U_3O_8. The schist is associated with marble and pegmatite, but only the schist was anomalously radioactive.

Coarse-grained granite from a stock pile of granitic and pegmatitic material at the Sanga Negra tin and tungsten mine (loc. 24) south of Encruzilhada (Leinz and Pinagel, 1945) contained 0.004 percent eU_3O_8 and 0.003 percent U_3O_8. Several localities on the road between Encruzilhada and the mine showed minor anomalies but were not sampled.

CONCLUSIONS AND RECOMMENDATIONS

The scintillation-counter road traverse of approximately 5,000 kilometers, as well as detailed scintillation-counter testing of quarries and mines, covered a large percentage of the rock types of southern Brazil but has revealed only a few uranium occurrences, all of low grade. The reason for this may be twofold: (1) uranium originally may have been sparsely distributed; and (2) even if it had been deposited in large quantities, much of it probably would have been removed from surface exposures during the deep weathering that has affected most of the rocks of the region.

Thus, it may be that uranium will be found in greater concentrations in outcrops or road cuts only: (1) where the original deposit was so large or high grade that tropical weathering has been unable to remove all the uranium; or (2) where suitable fixing material such as carbonaceous matter or coal (Haynes and Pierson, 1957) has precipitated and held uranium derived from ground water or from hydrothermal sources.

Because of the difficulties of interpreting low-grade uranium occurrences, detailed geologic studies of the known uranium occurrences of south Brazil are advisable before doing more reconnaissance. Such studies will give information about the origin of the occurrences and their behavior under extreme weathering conditions, and thus provide means of interpreting the results of reconnaissance studies.

Detailed geologic studies could be made at localities 18 and 21. Locality 18 is near the alkalic stock at Lages, Santa Catarina. Here highly altered alkalic rock from a dike in the Rio do Rasto group contained 0.026 percent U_3O_8. Locality 21 is at the Passo das Tropas fossil-plant locality in Rio Grande do Sul. At this place highly altered rock of the Rio do Rasto group contained 0.029 percent U_3O_8. Additional studies of pegmatites, such as at localities 1 and 8, will probably not be worthwhile because, although the uraniferous material of small pockets in the pegmatites is often high in grade, the total tonnage is usually small.

If more reconnaissance is done, the most favorable geologic environments for work, exclusive of the coal basins, appear to be the areas of alkalic rocks and regions of metalliferous deposits. Reconnaissance in areas of alkalic rocks should include more work on the stock at Itatiáia, where preliminary work has disclosed a radioactive occurrence (loc. 3), as well as more work at the alkalic stock near Lages. Other alkalic rock bodies are listed by Oliveira and Leonardos (1943) and by Moraes (1956) and include the occurrences at Jacupiranga and São Sebastião Island in the State of São Paulo, and at Tinguá and Cabo Frio Island in the State of Rio de Janeiro. These, and perhaps eventually all, localities listed by Oliveira and Leonardos might be worth testing.

Metalliferous deposits (Ferreira, 1949) that could be checked for radioactivity include the copper deposits at Itapeva, São Paulo; occurrences of vanadium at Santaria, copper at Bocaiuva and lead at Cerro Azul, all in the State of Paraná; deposits of magnetite, wolframite, galena, chalcopyrite and molybdenite from various places in Santa Catarina such as Blumenau, Itajaí, Brusque and Anitopolis; copper deposits at Camaqua, Santo Angelo and Santa Rosa, Rio Grande do Sul; and silver deposits at Soledade and Passo Fundo, Rio Grande do Sul. Possibly more work also should be done in the Encruzilhada area of tin and tungsten deposits in Rio Grande do Sul.

Finally, museum and private rock and mineral collections could be checked more thoroughly. This could be followed by field examinations of any localities from which radioactive specimens came. One such locality, not tested, to date, is the trap rock in the vicinity of Caxias do Sul in Rio Grande do Sul. A specimen of moderately radioactive amygdaloidal melaphyre from this region was noted in the rock and mineral collection of the Escola da Engenharia, University of Rio Grande do Sul at Porto Alegre.

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