RESOURCE COMPILATION SECTION

Radioactive Source Materials in Los Estados Unidos de Venezuela

By Donald G. Wyant, William N. Sharp, and
Carlos Ponte Rodríguez

Trace Elements Investigations Report 222

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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Geology - Mineralogy

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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

RADIOACTIVE SOURCE MATERIALS IN LOS ESTADOS UNIDOS DE VENEZUELA

By

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del Ministerio de Minas e Hidrocarburos
de Los Estados Unidos de Venezuela

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Trace Elements Investigations Report 222

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RADIOACTIVE SOURCE MATERIALS

IN

LOS ESTADOS UNIDOS DE VENEZUELA

by
D. G. Wyant
W. N. Sharp
and
Carlos Ponte Rodríquez

ABSTRACT

This report summarizes the data available on radioactive source materials in Los Estados Unidos de Venezuela accumulated by geologists of the Dirección Técnica de Geolgía and antecedent agencies prior to June 1951, and by the writers from June to November 1951.

The investigation comprised preliminary study, field examination, office studies, and the preparation of this report, in which the areas and localities examined are described in detail, the uranium potentialities of Venezuela are summarized, and recommendations are made. Preliminary study was made to select areas and rock types that were known or reported to be radioactive or that geologic experience suggests would be favorable host rocks for uranium deposits. In the office, a study of gamma-ray well logs was started as one means of amassing general radiometric data and of rapidly scanning many of the rocks in northern Venezuela; gamma-ray logs from about 140 representative wells were examined and their peaks of gamma intensity evaluated; in addition samples were analyzed radiometrically, and petrographically.

Radiometric reconnaissance was made in the field during about 3 months of 1951, of about 12 areas, including over 100 localities in the State of Miranda, Carabobo, Yaracuy, Falcón, Lara, Trujillo, Zulia, Mérida, Táchira, Bolívar, and Territory Delta Amacuro. During the course of the investigation, both in the field and office, information was given about geology of uranium deposits, and in techniques used in prospecting and analysis. All studies and this report are designed to supplement and to strengthen the Dirección Técnica de Geologías's program of investigation of radioactive sources in Venezuela now in progress.

The uranium potentialities of Los Estados Unidos de Venezuela are excellent for large, low-grade deposits of uraniferous phosphatic shales containing from 0.002 to 0.027 percent uranium; fair, for small or moderate-sized, low-grade placer deposits of thorium, rare-earth, and uranium minerals;

poor, for high-grade hydrothermal pitchblende deposits; and highly possible for small, medium- to high-grade deposits of carnotite-or copper-uranium bearing sandstone.

Recommendations for the Venezuelan uranium program include 1) the systematic collection of a mass of general radiometric data by examining sample collections, expanding the gamma-ray log program, encouraging the use of Geiger counters by field geologists, and by enlisting the aid of the general public; 2), the examination of specific areas or localities, chosen on the basis of geologic favorability from the results of the amassing of data, or obtained by hints and rumors; 3), the organization of a unit within the Dirección Técnica de Geología to direct, collect, and collate radiometric data.

It is emphasized that to be most fruitful the program requires the application of sound and imaginative geologic theory.

INTRODUCTION

The purpose of this report is 1) to summarize the currently available data regarding radioactive source materials in Venezuela, especially sources of uranium; 2) to describe in detail localities examined in the field or studied by gamma-ray logs, and to summarize their uranium potentialities; and 3) to recommend areas and rock types that merit additional study, methods to obtain additional radiometric data, and the facilities required for the program of search for radioactive material that is already in progress by the Dirección Técnica de Geología del Ministerio de Minas e Hidrocarburos de los Estados Unidos de Venezuela.

A treatise on the geology of Venezuela has no place in this report, and is not attempted. In the section describing localities examined, however, enough of the geologic frame-work and local detail are given so that the description of each area or locality is a self-contained unit. It should be emphasized that in further study of radioactivity in Venezuela the approach most likely to be productive of practical results is, in the long run, that of the complete historical geology of geologic provinces, areas, or other entities. By complete historical geology is meant the knowledge, in detail and in general, of geologic events, and would necessarily include the study and application of the geologic processes that tend to concentrate or to disseminate the mobile element uranium. Such a treatise would be invaluable from the standpoint of general knowledge, from which practical values are derived.

Status of investigations of radioactivity in Venezuela

The first known investigation for radioactivity in Venezuela is that published in 1939 by Otero, Beaujon, Prado, and Giménez (1) (reference at end of report), on the radioactive hot springs of Las Trincheras, State of Carabobo. Uranium minerals were first discovered in Venezuela in 1943 by Davey (2) from the pegmatities of Timotes, and Carmén, State of Mérida. Other investigations by members of the Dirección Técnica de Geología for radioactive minerals were summarized by Schwarck Anglade (3) in 1951. He includes the references above (1, 2); two other reports on the pegmatites of the Andes by López, Aguerrevere, and Davey (4), and by Schwarck Anglade (5); another report on the springs of La Trincheras by Rúbio (6); and laboratory examinations by Galavís of black sand concentrates from Evequí, Urimán, Territory Amazonas (7), of fluvatile sands from various places in Territory Amazonas (8), and the Gran Sabana, State of Bolívar (9). Since June 1951, radioactive minerals have been reported from rio Candaleria, State of Bolívar by Perfetti and Candiales (10), and from Santa Catalina, Territory Delta Amacuro by Schwarck Anglade (11).

In 1945, Worcester (12) also examined the uranium possibilities of pegmatites near Mérida for an agency of the government of the United States of America, and in 1950, Larson (13), U. S. Mineral attaché in Lima, Perú, made a brief tour through Venezuela at the request of the Venezuelan government.

Larson's report on the uranium possibilities of Venezuela, prepared in collaboration with the Dirección Técnica de Geología, contained a series of recommendations. Some of them pertained to the need for attracting the interest of prospectors and mining men by revising and clarifying the 1945 mining law and possibly by offering a bonus for the discovery of uranium ore. Other recommendations were to examine rock and mineral collections, visit areas in the Andes and the Guayana, and request the assistance of two geologists from the United States government.

Accordingly, at the request of the Venezuelan Government, Donald G. Wyant and William N. Sharp, geologists of the United States Geological Survey, arrived in Venezuela in June 1951. Carlos Ponte Rodríguez, geologist of the Venezuelan Dirección Técnica de Geología, was assigned to be in charge of a program of the Dirección investigating radioactive source materials in Venezuela. He accompanied Wyant and Sharp in the field, and collaborated in some office studies.

The objectives of Wyant and Sharp were: first, to give information to members of the Dirección Técnica de Geología about some of the pertinent facts concerning the geologic occurrence of uranium ores, and to show them also some of the techniques used in field examination and laboratory analysis; second, to appraise the uranium potentialities of Venezuela; and third, to make recommendations for future work by Venezuelan governmental agencies. A corollary to these three objectives was to interest people in Venezuela in prospecting for uranium. The objectives of the assignment are in part fulfilled by this report and brief reports on current progress submitted to Dr. Schwarck Anglade during field work. Information on the geology of uranium deposits was given in part in talks, both formal and informal, to members of the Dirección Técnica de Geología, in part by discussion in the field, and in part by recommending selected references for study. Information in field and laboratory techniques was given in formal and informal talks, and in practice both in the field and in a small radiometric laboratory set up in Caracas. Interest in searching for uranium has been stimulated formally, by a talk before the Associación Venezolana de Geología, Minería, y Petróleo (Venezuelan Society of Geology, Mining and Petroleum), and informally, by discussions with many people, especially petroleum company geologists and engineers, but also mining engineers, and others. The program of uranium research of the Dirección Técnica de Geología is an active one, and the preliminary work we have jointly accomplished was designed to coordinate with and to expand that program.

Potential host rocks of uranium in Venezuela

By analogy with the geologic occurrence of uranium deposits in the United States of America and elsewhere in the world, and by preliminary study of the geology of Venezuela both by reading and by conversation with resident geologists, it was possible to compile a list of certain rock types that offered possibilities of being potential host rocks for uranium deposits in Venezuela. This list was then used to make plans for field or laboratory examinations.

Uranium deposits have been found in many types of host rocks throughout the geologic column. In general, however, in any search for uranium the following types of rocks offer more promise than others: 1) Thin marine black shales, especially of Paleozoic age or older; 2) all marine phosphate deposits, including phosphatic nodules in shale; 3) porous,"red beds", especially those continental formations that contain carbonized plant remains, copper stains and intrusive igneous rocks; 4) mesothermal argentiferous base-metal veins in siliceous, grantic or volcanic country rock, and replacement deposits in limestone; 5) lignite, especially seleniferous lignite immediately underlying unconformities; 6) heavy minerals concentrated in alluvial deposits, and 7) pegmatites (Bain, McKelvey and Nelson, Fischer, Page and Everhart; 14 through 18).

Of these seven main types of rocks, all are probably present in Venezuela, although base-metal veins are not abundant. Accordingly, trips were planned to examine: 1) the black shales of the Colón and Misoa-Trujillo formations and any others found 2) the phosphatic "fish-bone" beds of La Luna and the Colón formations, 3) the cupriferous terrestrial La Quinta and Tomón formations and the terrestrial Roraima series; 4) lead veinlets and gold-quartz veins; 5) several lignite and coal beds; 6) beach and stream alluvial deposits; and 7) the uraniferous pegmatities in the States of Mérida and Bolivar. In addition, of course, many other rocks, as well as crude oils, spring waters and deposits were examined radiometrically in the field, and studied in the office. Gamma-ray logs made for the oil companies were also examined. All data accumulated will serve a useful purpose, either by contributing to a more comprehensive knowledge of the general radioactivity of the rocks of Venezuela, or by indicating specific areas of abnormal radioactivity.

Radiometric equipment

Radiation detectors (Geiger counters) used during the present reconnaissance for uranium in Venezuela were field survey meters, field scalers, and laboratory scalers.

The field survey meters used were equipped with 6-inch glass-walled Geiger probes that can detect either gamma radiation if the movable shield is closed, or beta and gamma radiation if the shield is open. These probes normally record about 50 impulses per minute. This conveniently portable instrument is powered by dry cell batteries and equipped with a rate meter rather than an impulse register. The rate meter circuit registers by means of a needle fluctuating across a calibrated dial, the average current flow resulting from amplified pulses. The pulses reflect ionizations of the gas in the Geiger tube when ionized by charged particles or rays (alpha and beta particles; gamma and cosmic rays). The dial is graduated into divisions that can be calibrated in milliroentgens per hour, and is equipped with a sensitivity or range switch that converts full-scale reading to 0.2, 2, or 20 milliroentgens per hour. The needle position on the dial may be read directly in milliroentgens per hour, although this is not entirely correct in the field inasmuch as the roentgen is a unit of gamma ray emission only and also because the meter may not be accurately calibrated in terms of milliroentgens or adjusted properly for the different range positions.

In the field, observations were made by watching the needle for two minutes or longer, and recording the minimum, maximum, and average number of scale divisions. Also recorded were the sensitivity or range position, and whether the shield was open to permit detection of both beta and gamma radiation, or closed to permit detection of only gamma rays. The system of recording such information in the field which will be used throughout this report may be symbolized as follows: 2 - 7; $\overline{5}$ (B,) 0.2 MR/hr scale), and translated to mean 2 minimum - 7 maximum; $\overline{5}$ average number of scale divisions (shield open, measurement made on the 0.2 milliroentgen per hour scale). Where not indicated, the 0.2 MR/hr scale was used, and the shield closed (6).

For rapid scanning in the field the normal 6-inch Geiger probe of the field survey meter was replaced with either a 20-inch metal probe for use on horse, or in rapid walking, or with two 40-inch metal probes for semi-permanent installation on a Jeep. The 20-inch probe operates at 900 volts and normally records 2000 counts (impulses) per minute. The 40-inch probes operate at 1200 volts and together normally record about 4000 counts per minute. Both 20- and 40-inch probes can detect gamma radiation only, and although not calibrated in terms of milliroentgens per hour, are of great value in rapid reconnaissance or the detailed mapping of radioactive rocks.

For more accurate registration of impulses or "counts" per unit time in the field a portable scale-of-eight scaler made by the Berkeley Scientific Company was used. This instrument feeds every eighth impulse into a mechanical register and each impulse from 1 to 8 is also noted on a small dial. The total number of "counts" at any moment may, therefore, be read from the mechanical register and the small dial.

For quantitative determination of the radioactivity of samples, two scale-of-64 scaler units, model no. CGM-3B, manufactured by the

El-Tronics Company, Incorporated, were set up in the laboratory of the Dirección Técnica de Geología. These scalers were equipped with Thyrode Geiger probes, model 1 B 85, made by the Victoreen Instrument Company. The probes, when mounted in a small quonset-shaped lead shield, the walls of which were 3 centimeters thick, normally detected no more than 0.5 "counts" per second. Calibrated standards from the Denver Radiation Laboratory of the United States Geological Survey were used to measure the radioactivity of samples. Radiometric analyses obtained are given in terms of percent equivalent uranium, which may be defined as the total radioactivity measured, but presented as if due only to uranium and its decomposition products in equilibrium.

Members of the Dirección Técnica de Geología of the Ministerio de Mines e Hidrocarburos were informed of the accepted methods of use and of the limitations of these instruments and of their maintenance and simple repair. In the laboratory, information was given about common methods of radiometric analyses, the detection of radium from the radon curve of "pelletized" samples, and about qualitative chemical determination of uranium in radioactive samples. In the field, information was given about currently accepted methods of reconnaissance and detailed examination.

Acknowledgments

The work could not have been accomplished without the aid of the Dirección Técnica de Geología of the Ministerio de Mines e Hidrocarburos of Venezuela, and it is a pleasure to acknowledge the hearty cooperation given by all members of this organization, especially that of Armando Schwarck Anglade, Director, and Luis Ponte Rodríguez, chief of the department of mining geology and petroleum. Information on the geology of various parts of Venezuela was also received from the following members of the Dirección: 1) Alirio Bellizia, 2) Gabriel Dengo, 3) Juan Evanoff, 4) Clemente Gonzáles de Juana, 5) José Nancý Perfetti, and 6) Gustavo Rivero Nadal. We were accompained in the Caracas area by Gabriel Dengo, in western Zulia by Raúl Laforest, in parts of the Andes by Alberto Vivas R, and Diego Gonzáles M, and in areas south of the Orinoco by Gustavo Márquez, Alirio Bellizia, Luis José Candiales, and José Nancy Perfetti. In the office, Cecilia Martin Bellizia and Alirio Bellizia examined rock and sand samples petrographically, Antonio Cárdenas made most of the radiometric analyses, and the draftsmen of the Dirección staff, ably headed by Sr. Rosson prepared the illustrations.

It is impossible to list every one of the oil and mining company employees who freely gave us assistance, either in the form of maps, gamma logs, data, suggestions, or housing, but we would like to acknowledge particularly the assistance of George Heyl, Karl Dalmus, Gordon White, F. Walker Johnson, M. G. Ball, and Fred W. Kerr of the Creole Petroleum Company; Keith Miner and Jay Beaver of the Petrotec Company; Ely Mencher, Verner Jones, and Norman Weisbord of the Socony-Vacuum Petroleum Corporation; J. U. Patterson, M. Forrer, and

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LOCALITIES EXAMINED RADIOMETRICALLY

Introduction

The rock types and areas of interest that were determined by preliminary bibliographic study and conversation with geologists in Caracas were compiled on maps and lists, and several trips then made to examine as many of the types and areas as was possible. The routes taken are shown in figure 1, and the localities examined in relation to regional geology are shown in figure 2. Stratigraphy is shown on chart 1. Individual reports written of each locality or group of localities have been amended and arranged approximately by area, rather than in chronological order or by rock type. The localities discussed below were examined for radioactivity in about three months of 1951. On June 22, a reconnaissance of the Caracas area was made. From August 20 to 28, radiometric examinations were made at Las Trincheras, State of Carabobo and in the northern part of the State of Falcón. From September 4 to 8, a radiometric reconnaissance was made between Barquisemeto, State of Lara, and Chejendé, State of Trujillo. From September 22 to October 19, radiometric examinations were made at Aroa, State of Yaracuy; between Guarico, State of Lara and Trujillo, State of Trujillo; in the State of Zulia; and in the Andean States of Mérida, and Táchira. From November 7 to 28, a radiometric reconnaissance was made in the State of Bolívar and in the Territory Delta Amacuro.

The Caracas area, Distrito Federal, and State of Miranda

The Caracas area extends from the vicinity of Caracas north to the Caribbean Sea (fig. 1), and includes a representative part of the Coast Range of Venezuela. Some of the rocks comprising the range were examined radiometrically on June 26, 1951 in company with Gabriel Dengo who has written an authoritative account of the area (19).

General geology

The area is composed predominantly of meta-sedimentary rocks although some meta-igneous, and unmetamorphosed igneous rocks have been described (fig. 2). The oldest known rocks of the area, the Sebastopol complex [(19) pp. 50-53], consist predominantly of granitic gneiss, upon which lie a thick meta-sedimentary series called the Caracas group [(19) pp. 53-67]. The Caracas group is composed, in order of decreasing age, of conglomeratic quartz-mica schists with a limestone member, crystalline limestone, calcareous and graphitic schists, and sericite-epidote schists. These rocks are termed respectively, Las Brisas formation, Antímano formation, Las Mercedes formation, and Tacagua formation. They are interlayered with serpentine and amphibolites, and have been injected by narrow dikelets of acidic granitic rocks [(19) pp. 87-88]. In addition to these formations there are different phases caused by varying degrees of dynamo-thermal metamorphism, as for example the paragneiss, called the Peña de Mora formation that is probably equivalent to Las Brisas formation [(19) p. 94]. Overlying these metamorphic and igneous rocks at Cabo Blanco, west of Maiquetía, are sands and gravels of Miocene and Pliocene age. All these rocks have been gently folded and faulted. The traces of axial planes of folds and of fault surfaces trend predominantly east or northeast; the faults, both normal and reverse, dip either to the north or south and probably represent several periods of deformation, and not simple contemporaneous block-faulting. Most of the rocks of the Caracas group are undoubtedly of sedimentary origin and some at least are probably of Cretaceous age. They are, therefore, probably correlatives of sandstone, limestone, and shale units of Cretaceous age, some of which are radioactive in other parts of Venezuela. Metamorphism and faulting are post-Cretaceous in age.

Radiometric observations

Radiometric observations were made at two points along the Caracas-Maiquetía highway, in tunnel 3 of the Caracas-Maiquetía superhighway now in construction, and at two points along the Mamo river west of Maiquetía. The rocks examined in this brief reconnaissance were part of Las Brisas formation, part of Las Mercedes formation, part of the Tacagua formation, serpentine, and part of the Peña de Mora gneiss.

A limestone member of Las Brisas formation was examined in an operating quarry 7 kilometers up the Mamo river from its mouth. The limestone is gray coarsely crystalline and highly sericitic; it contains some graphite and green mica (mariposite?). The radioactivity observed was not appreciable, 0 - 3; $\overline{1.5}$ (B).

Part of Las Mercedes formation in fault contact with Peña de Mora gneiss, was examined about 12 kilometers from Caracas along the road from Caracas to Maiquetía. Las Mercedes formation is composed of pink-weathering mica schist with abundant white veinlets of calcite. Its radioactivity was 0 - 4; $\overline{2}$ (B). The Peña de Mora gneiss is here a hard blocky-weathering biotite-quartz-feldspar augen-gneiss that is well laminated. The radioactivity observed was 0 - 6; $\overline{3}$ (B).

The uppermost beds of Las Mercedes formation and basal beds of the overlying Tacagua formation were examined in the road cut near the portal of tunnel no. 3 on the new Caracas-Maiquetía superhighway. Gray pyritic, graphitic, calcareous schist of Las Mercedes formation grades upward within a few feet into green schists of the Tacagua formation. The radioactivity of these rock types was not appreciable, 0 - 5; $\overline{2}$ (B).

Within the tunnel, typically dark-green slickensided serpentine is exposed. The radioactivity was 0 - 4; $\overline{1}$ (B). Serpentine examined at Plan de Manzano, 10 kilometers from Caracas along the road from Caracas to Maiquetía was also not appreciably radioactive; the radioactivity was 0 - 2.5; $\overline{0.5}$ (B).

The Tacagua formation was also examined along the Mamo River road about 3 kilometers north of the limestone quarry. The rock is a coarsely foliated, coarse-grained, chlorite-sericite-quartz gneiss. The radioactivity observed was not appreciable, 0 - 5; $\overline{1.5}$ (B).

Summary and recommendations

In the brief radiometric reconnaissance of some of the rocks exposed in the Caracas area, none seem to be appreciably radioactive. As is to be expected, the serpentines appear to be least radioactive, and the Peña de Mora gneiss the most radioactive of the rocks examined. Neither graphitic layers nor pyrite impregnations were abnormally radioactive. A more detailed study of radioactivity of the rocks of the Caracas area, making use of the car-mounted gamma probes, is required before the area can be classed as of no further interest for radioactive source material. In the study, it should be recalled that the rocks of the Caracas group may possibly include the metamorphosed equivalents of the radioactive beds of La Luna and Colón formations.

Las Trincheras Hot Springs and vicinity, State of Carabobo

Abstract

The radioactive hot springs of Las Trincheras, and some of the surrounding area, State of Carabobo, Venezuela, were examined with a portable Geiger counter in August 1951. The hot springs are in granitic rocks intruded into the Caracas series of metamorphic rocks that are of probable Cretaceous age. The granite is in part foliated, and contains abundant schist and gneiss xenoliths and some simple granite pegmatite dikelets and felsite dikes.

Markedly radioactive salts, precipitated on the surface of schist from undetectably radioactive hot water, cover an area of about 1 meter square at the Fuentes del Sur, and weakly radioactive salts were observed at the west end of the upper pond. The radioactivity of these two areas averaged, respectively, ten and two times the local background level of radioactivity. A sample of the most radioactive salt analyzed in the Trace Elements Section Laboratory of the U. S. Geological Survey in Washington, D. C., contains 0.072 percent equivalent uranium, 0.001 percent uranium, approximately 0.01 percent thorium dioxide, and less than 1.17×10^{-9} curies per gram of radium. Semiquantitative spectrographic analyses for metals in this salt show it to be composed predominantly of silicon, and subordinately of calcium, sodium, aluminum, manganese, and potassium, with lesser amounts of magnesium, iron, and strontium. Neither the water, gas, algae, mud and the rest of the salts precipitated from the hot water at Las Trincheras, nor the granite, schist, and gneiss in the area examined surrounding the hot springs were abnormally radioactive.

Most of the radioactivity of the salts is caused apparently by thorium and its disintegration products, perhaps in the form of carbonates, precipitated from the hot alkaline water. The radioactive elements are probably derived from underlying minerals that probably form small bodies, such as hydrothermal veinlets, disseminations, or pegmatites.

Because of the paucity of uranium the area is classed, at least temporarily, as one in which additional study is not merited.

Introduction

The Hot Springs at Las Trincheras, district Puerto Cabello, State of Carabobo, are about 19 kilometers north of Valencia, and 24 kilometers south of Puerto Cabello, at an altitude of about 350 meters in the gorge of the Rio Agua Caliente (figs. 1 and 2). They have been known since colonial times and have been investigated by many scientists. The most thorough investigation was that by Otero, Beaujon, Prado, and Giménez in 1939 (1), who detected an average of 238 millimicrocuries of radiation in the gas emitted from the central spring, a maximum of 26.4 millimicrocuries in 10 liters of water, and from 5.9 to 56.6 millimicrocuries per kilogram in the mud. The radioactivity of the samples disappeared within a few days and was probably caused by radon or thoron. Otero, Beaujon, et al. (1), observed the granitic rocks in the vicinity of the hot springs, and concluded that the source of both heat and radioactivity might be a cooling batholith underlying the area.

In February 1950, Dr. Enrique Rúbio S. (6) examined the hot springs and some of the surrounding area with a Geiger counter, and found no indication of radioactivity.

The writers examined the area of Las Trincheras on August 21 and 22, 1951, making radiometric observations of the hot springs and some of the surrounding area.

Geology

The area of the hot springs of Las Trincheras has not to our knowledge been mapped in detail, but reconnaissance has been done by Aguerrevere and Zuloaga (20), Hess and Dengo (21), Rivero (22), and Liddle (23). Aguerrevere and Zuloaga recognized a porphyritic granite in the area that is probably intrusive into the Caracas series of metamorphic rocks of Cretaceous age. Dengo and Hess observed two types of granitic rock in the area, one coarse-grained and unmetamorphosed, the other fine-grained and metamorphosed.

In the brief examination made by the writers, granitic rock was examined along the road from about 1 kilometer northeast of Las Trincheras eastward to the vicinity of La Entrada (fig. 3). The rock appears megascopically, to be a medium- to coarse-grained brown granite and gneissoid granite with minor variations in grain size, cut by a few simple granite pegmatite dikelets which range in thickness from a few centimeters to 0.5 meters, and by some fine-grained felsite dikes. Xenoliths of dark gray-green mica-schist are locally abundant; a large body of calcareous mica-schist about 1 kilometer north of Las Trincheras may be a large xenolith or possibly a septum, separating two different granitic types. The degree of foliation of the granitic

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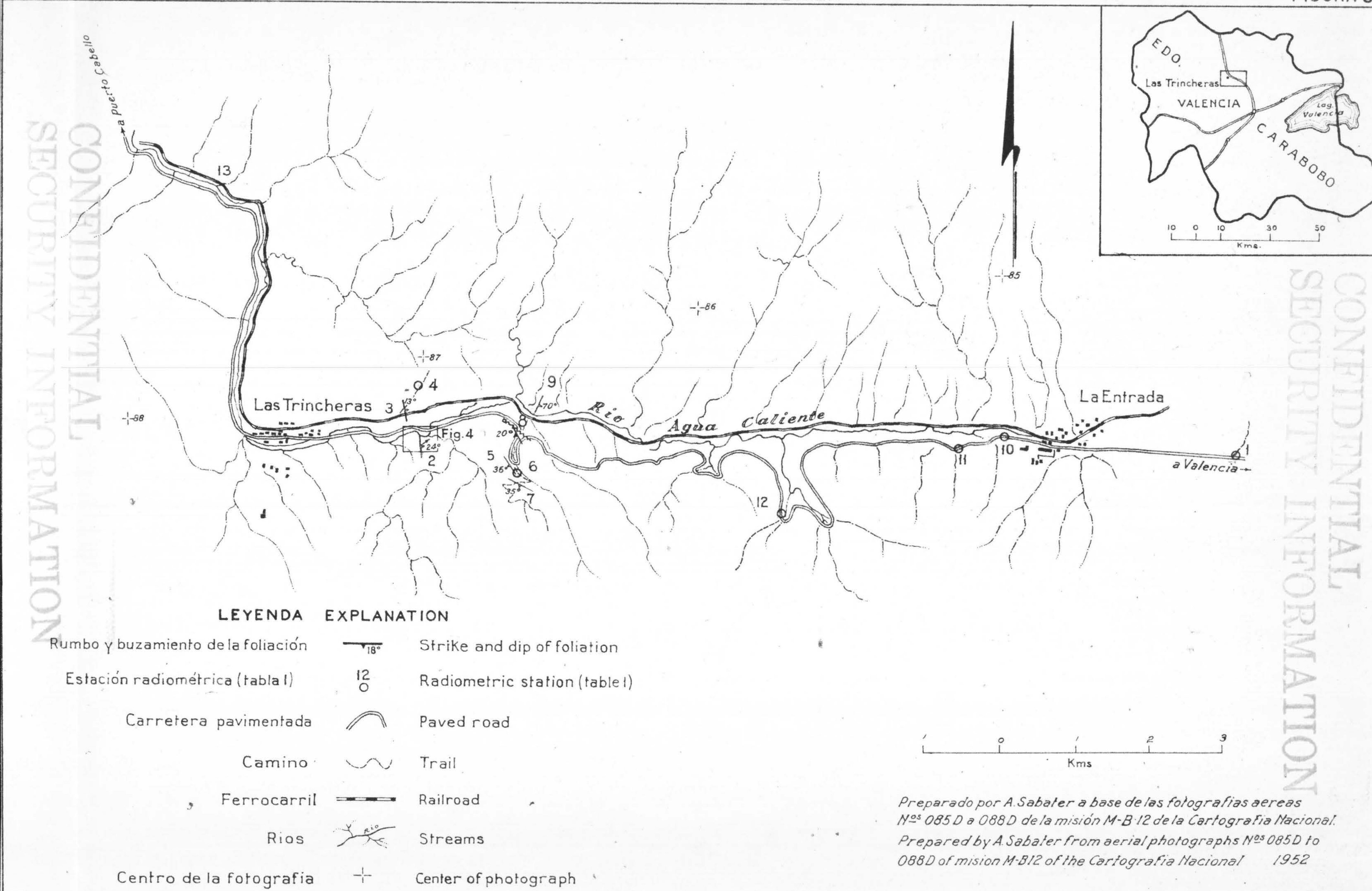
FIGURA 3



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CROQUIS DEL AREA LAS TRINCHERAS, ESTADO CARABOBO
SKETCH MAP OF LAS TRINCHERAS AREA, STATE OF CARABOBO

rocks ranges from none in the vicinity of La Entrada to moderate in the vicinity of Las Trincheras. The foliation varies in attitude but in general strikes NNW and dips about 25° SW. The attitude of foliation of the schist and gneiss, on the other hand, strikes N. 6°-40° E., and dips either west or east at any angle. Areas north of the rio Agua Caliente appear white where the rock is exposed. This material, where observed, is, megascopically, a sericite-quartz gneiss.

At Las Trincheras (fig. 4), the hot springs issue from the side of a small gully subsidiary to the rio Agua Caliente and flow into small ponds. Gas issues from the Fuente Central, and white to ocherous salts have formed along the sides and ends of the tanks. Rock is exposed only in the small rectangle of concrete enclosing the Fuentes del Sur. Here the rock is, megascopically, a gray-green, siliceous biotite schist encrusted with a layer a few millimeters thick of botryoidal white salt deposited by the hot water. Small pyrite crystals and a black manganiferous mineral, in places, are abundant under the salt incrustation. The surfaces of schistosity strike approximately N. 10° E. and dip 24° W.

Samples were taken of the rock and incrusting salt, but have not yet been studied petrographically.

Radioactivity

Las Trincheras Springs

At Las Trincheras (fig. 3, no. 2) the background level of radioactivity on alluvium in front of the hotel (fig. 4) was 1 - 3; $\bar{2}$ (B). Radiometric observations were made of the water in tanks 1 and 2 (fig. 4) and of the Fuentes del Sur and Santa Isabel. Radiometric observations were also made of the ocherous mud at the edge of the ponds, of the salt incrustations around the edges of the ponds, of algae, and of the gas issuing from the Fuente Central. Material other than some of the salt incrustations, is not appreciably radioactive, and most of the salt incrustations are not radioactive.

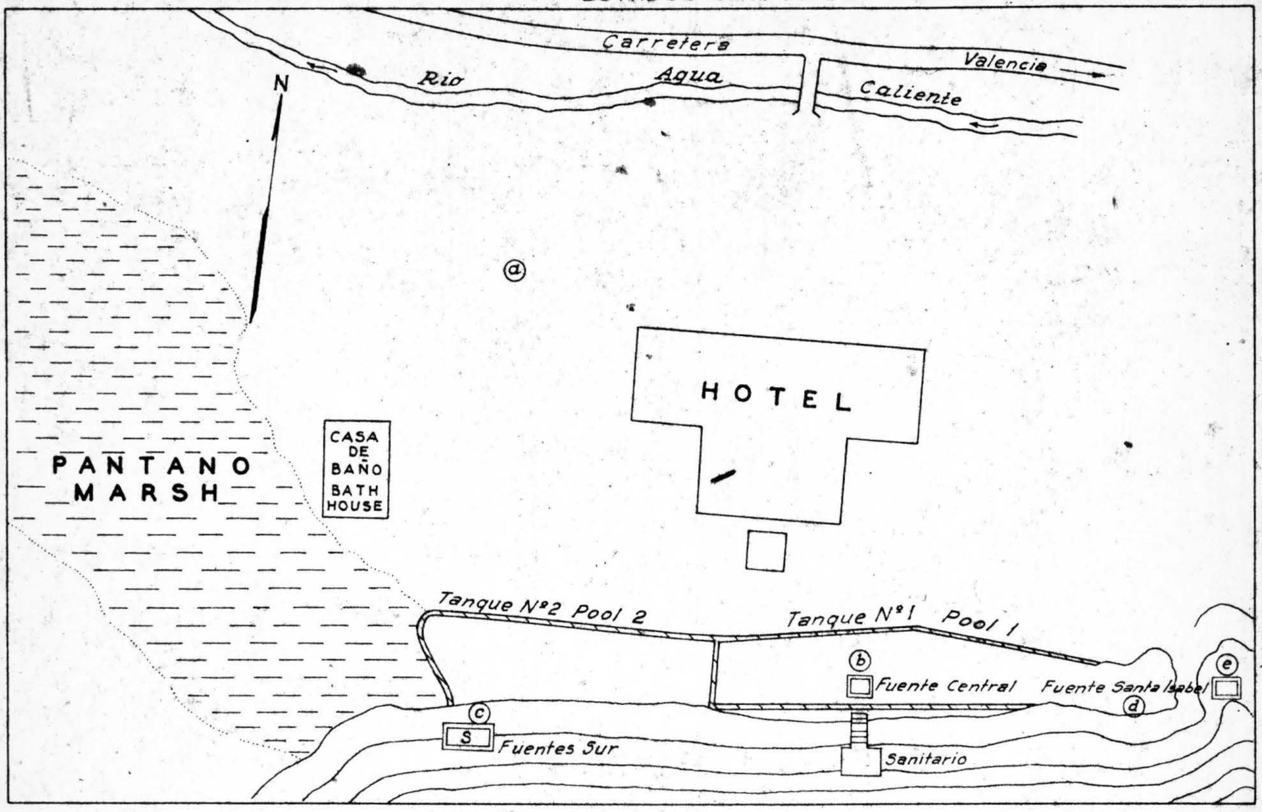
At the west end of tank 1, the salt contained about twice the background level of radioactivity [3 - 5; $\bar{4}$, (G)]. At the Fuentes del Sur some of the salt incrustations are markedly radioactive. The area of markedly radioactive salts is about 1 square meter, and the radioactivity of this area is about 10 times the background level, ranging from 10 to 30 scale divisions and averaging 20, both gamma and beta-gamma. The fresh schist beneath the radioactive salt is not radioactive.

Samples.--Samples were taken of the water from the Fuente Central (number C A-149) and of schist incrusted with radioactive salt (number C A-150). Sample C A-150 was analyzed by the Trace Elements Section

UNITED STATES DEPARTMENT OF INTERIOR
GEOLOGICAL SURVEY

PREPARED BY THE
DIRECCION DE GEOLOGIA
MINISTERIO DE MINAS E HIDROCARBUROS
ESTADOS UNIDOS DE VENEZUELA

FIGURA 4



LEYENDA EXPLANATION

- [Q] Aluvión y talud / Alluvium and talus
- [S] Esquisto / Schist
- ⓐ Observación radiométrica / Radiometric observation

OBSERVACIONES RADIOMETRICAS
RADIOMETRIC OBSERVATIONS

LOCALIDAD LOCATION	RADIOACTIVIDAD RADIOACTIVITY 1/
ⓐ	1.2-3; $\overline{2}$ (G, B) 1/
ⓑ	1.5-3; $\overline{2.7}$ (B)
ⓒ	10-30; $\overline{20}$ (G, B)
ⓓ	3-5; $\overline{4}$ (G)
ⓔ	1-3; $\overline{2}$ (B)

1/ Minimum-maximum; $\overline{\text{valor promedio}}$ de las divisiones de la escala (B= beta-gamma, G= gamma solamente).

Minimum-maximum; $\overline{\text{average}}$ number of scale divisions (B= beta-gamma, G= gamma only).

CROQUIS DE LAS FUENTES TERMALES LAS TRINCHERAS, EDO. CARABOBO
SKETCH OF LAS TRINCHERAS HOT SPRINGS, STATE OF CARABOBO

SEGUN: OTERO Y OTROS
AFTER: OTERO ET AL

1951

Washington Laboratory of the U. S. Geological Survey. This radioactive salt incrustation contains 0.072 percent equivalent uranium, 0.001 percent uranium by chemical analysis, about 0.01 percent thoria (ThO_2) by spectrographic analysis, and less than 1.17 x 10^{-9} curies per gram of radium. The radioactivity of the salt is thus attributable to thorium, and its decomposition products, although some of the radioactivity may be caused by the radium. This salt was also analyzed spectrographically for metals with the following semiquantitative results:

Over 10 percent	1 to 10 percent	0.1 to 1.0 percent	0.01 to 0.1 percent	0.001 to 0.01 percent	0.0001 to 0.001 percent
Si.	Ca, Na,	Mg, Fe,	Ba, Ti,	V, Pb, Y,	Ag.
	Al, Mn,	Sr	Ni, Sc	B, La, Cr,	
	K			Zr, Ba, Cu	

Water sample C A-149 should be analyzed for uranium when equipment is available in Caracas.

The disappearance of radioactivity from water samples "in a few days" noticed by Otero, et al. (1), suggests that gaseous radioactive elements other than thoron may be present. In the Caracas laboratory part of Sample C A-150 was ignited and pelletized, and the increase in radioactivity over a period of 30 days measured. The resulting curve indicates that radon may be present.

Origin.--The radioactive salt was formed by the evaporation of the undetectably radioactive hot water issuing from the Fuentes del Sur. Why only part of the salt should be radioactive is not known although three suggestions may be made: 1) there is a local chemical difference in the schist that causes the radioactive material to precipitate in a local area; 2) in the course of a relatively short time the rising water completely removed the radioactive minerals from the source rocks; or, 3) the hot water containing radioactive materials derived from an underground source, as in alternative 2), changed its course so that it no longer traversed radioactive material.

Areas near Las Trincheras Springs

Radiometric traverses were made along roads and trails near Las Trincheras (fig. 3) with essentially negative results, although the unaltered granitic rock, as in other places in the world, may be slightly more radioactive than the enclosing schist and gneiss. Radiometric observations were made at 13 points or stations (table 1), and the counter was watched while walking between many of the stations.

Table 1.--Radiometric stations, Las Trincheras area

Location (No. on fig. 3)	Material	Radioactivity	Remarks
1	Granitic soil	1 - 4; $\overline{2}$ (G)	Background
2	Soil	1 - 3; $\overline{2}$ (G)	Background (fig. 4)
	Water, gas, algae, salt	1.5 - 3; $\overline{2.25}$ (B)	
	Salt crust	10 - 30; $\overline{20}$ (G, B)	Small area of radioactive salt
	Siliceous mica schist under salt	1 - 3; $\overline{2.5}$ (G)	
	Salt	3 - 5; $\overline{4}$ (G)	Salt at west end tank (fig. 4)
3	Mica, schist and quartz veinlets	1 - 4; $\overline{3}$ (G)	
4	Schist	1 - 4; $\overline{2}$ (G)	North end traverse
5	Gneissoid granite (?), siliceous, chloritized biotite bands, and altered schist xenoliths	1 - 3; $\overline{2}$ (G, B)	
6	Siliceous granite, slightly foliated	1 - 4; $\overline{3}$ (G, B)	
7	Gneissoid granite	1 - 4; $\overline{3}$ (G, B)	
8	Small fault in gneissoid granite and microgranite	3 - 5; $\overline{4}$ (G)	Radioactivity may be slightly less outside of fault zone
9	White sericite-quartz gneiss	1 - 3; $\overline{2.5}$ (G)	
10	Fresh granite and granite pegmatite	1.5 - 3.5; $\overline{3}$ (G)	
11	Granite, slightly foliated	1.5 - 3.5; $\overline{3}$ (G)	
12	Gneissoid granite	1 - 3; $\overline{2}$ (G)	
13	Contact between green calcareous schist to east and granite gneiss to west	1 - 3; $\overline{2}$ (G)	Gneiss may be slightly more radioactive than schist

Conclusions and recommendations

The radioactivity determined by Otero, Beaujon, et al. (1) in water and gas from Las Trincheras is probably caused by dissolved radon and thoron and from preliminary analyses it seems probable that the radioactive elements in the radioactive salt at Fuentes del Sur are predominantly thorium and subordinately radium, perhaps combined with some of the numerous carbonate ions in the water in the form of carbonates. Because the radioactivity of the water and gas is low, and the area of radioactive salts is small, it is concluded that the underlying deposit of thorium minerals may also be small. Either narrow hydrothermal veins, disseminated thorium minerals, or pegmatites would fit the available evidence.

Because of the presence of thorium rather than uranium, additional work in the Las Trincheras area does not seem justified at present.

Igneous rocks of the Paraguaná Peninsula, State of Falcón

The igneous rocks that crop out in the central Paraguaná peninsula, State of Falcón (fig. 5), were examined for radioactivity August 24 and 25, 1951. The peninsula is essentially a flat low-lying desert plain, in the center of which is the Cerro Santa Ana that rises about 800 meters above the plain and is flanked on the west, southeast, and north by a few lower hills.

The higher points are formed of igneous rocks, and were examined at Cerro San Ysidro, Cerro Santa Ana, near Cerro Tausábana, and near El Rodeo. The principal geologic work in the region, done by Aguerrevere (24, 25) for the Cities Service Oil Company, has not been published although his map is probably the source of the information on Bucher's map (26); other work has been done by Kehrer (27), Liddle (23), and Brandrat (28).

Geology and radioactivity

Many flat boulders and pebbles of black slate were observed in the ravines on the west side of Cerro San Ysidro, which may be Cretaceous sediments into which the felsic and mafic igneous rocks may be intruded [Aguerrevere (24)].

Cerro San Ysidro area

The area of Cerro San Ysidro examined is about 40 kilometers by road from Amuay and 8 from Pueblo Nuevo, on the hacienda of Sr. Davalillo. The edge of the granitic hill is abrupt and may represent either a fault-line scarp or an old marine shelf. In a traverse of approximately a kilometer the predominant rock observed is dark green, contains abundant plagioclase, and minor quartz and biotite, and is called, provisionally, a diorite. Some boulders of hornblende diorite were observed as well as small outcrops of granite and irregular pegmatite dikelets. Because the biotite has been converted to chlorite and some zones are fractured and brecciated, the diorite probably has been metamorphosed although no schistosity was noted. Two sheeted quartz veins, each over 6 feet thick, striking, in general, north and dipping about 40° east, were at one time prospected for gold. The quartz contains sparsely disseminated flecks of magnetite, pyrite, chalcopyrite (?), covellite (?), and galena (?). Sr. Davalillo reported they had been analyzed for gold and contained a small, but not a commercial, amount.

Samples of the quartz vein and of the igneous country rock were taken for petrographic study. The predominant country rock is hornblende diorite altered by hydrothermal solutions that contains xenoliths of quartz-sericite-chlorite schist.

The radioactivity of the diorite, granite, and granite pegmatite dikelets is 1 - 4; $\bar{3}$ (G, B), whereas that of the quartz veins is 0 - 2; $\bar{1}$ (G, B).

Cerro Santa Ana

The Cerro Santa Ana was examined about 2 kilometers north of Santa Ana. Most of the rock observed is a dark green, coarse- to medium-grained diorite composed of bladed feldspar and hornblende traversed by dikes of dark green aphanite, and by hornblende-plagioclase pegmatite. Samples of the rock taken for petrographic study, indicate that the country rock is dominantly hornblende diorite, diorite porphyry, and subordinantly amphibolite and diabase porphyry.

The radioactivity is subnormal, 0 - 1.5; $\bar{1}$.

Tausábana-El Rodeo area

On a road in and near Tausábana, coarse grained gray-green, red-weathering diorite (?) was observed. The radioactivity was 0.5 - 2; $\bar{1}$.

Near El Rodeo, dark, and presumably ultra-basic rock was examined. The rock is deeply weathered and contains dikelets of pyroxene and hornblende-pegmatite, small irregular masses of magnesite, and some serpentine. Its range in radioactivity was 0.5 - 2; $\bar{1}$.

Conclusions and recommendations

The absence of radioactivity in the igneous rocks of Santa Ana, Tausábana, and El Rodeo, and the lack of indications of metallic mineralization make these more basic rocks of little interest for uranium. The San Ysidro area, although not appreciably radioactive, may be worth additional study because of the presence of mineralized quartz veins and Cretaceous rocks.

Amuay Refinery, Paraguaná Peninsula, State of Falcón

Some of the crude oils of Venezuela contain appreciable vanadium according to Manger (29) and Dallmus (30), and because vanadium is commonly associated with uranium, and also as some evidence suggests that crude oil may be a transporting agent for uranium [Gott (31)] , it must be considered as a possible source of uranium in Venezuela. The field investigation of crude oils and refinery products for uranium began August 22 and 23, 1951, with the examination of the Amuay Refinery, owned and operated by the Creole Petroleum Corporation, Caracas, Venezuela.

The Amuay Refinery is on the southwest side of the Paraguaná Peninsula, State of Falcón, about 15 kilometers north of Las Piedras (fig. 5). The refinery makes a preliminary treatment of crude oil from the so-called Tiá Juana field, part of the Bolívar coastal field of the Maracaibo basin, after which the refined products are shipped to Aruba for cracking and other processing. The crude oil of the Tiá Juana field ranges in gravity from 13 to 28 A. P. I. [Nelson, et al. (32)] , and is produced largely from La Rosa and Lagunillas formations of Miocene age, although some is produced from the Icotea formation of Oligocene age [Ponte R. (33)] .

At the time of the investigation, the refinery was shut down for inspection and therefore the furnaces, tanks, and tubes were readily accessible. The various sludges, residues, scales, furnaces, etc. examined, as well as the brine-crude oil settling tank, were undetectably radioactive. Nevertheless, four samples (table 2) were taken for chemical analysis for vanadium and spectrographic analysis for rare metals. These analyses should be made in Caracas when equipment becomes available.

Table 2, Samples, Amuay Refinery, Paraguaná, State of Falcón

Sample No.	Material	Analyses	Remarks
1	Ash		Furnace floor fire chamber, burning Tiá Juana bottoms fuel oil (temperature unknown but very hot)
2	Sludge, mostly carbon		Oil tubes, atmospheric furnace (550°F)
3	Stack solids		Atmospheric furnace, Tiá Juana medium bottoms (14 A.P.I. gravity oil)
4	Sludge		Heat exchanger, heavy oil side

It is concluded that the Tiá Juana crude oil at Amuay is not uraniferous. At the Tiá Juana field in Zulia, crude oil is first run into settling tanks where about 20 percent of the brine is removed, according to Mr. Fred W. Kerr. For the sake of completeness, therefore, the tanks, valves, and settling ponds were examined radiometrically in October at Tiá Juana, with negative results. Mr. M. G. Ball suggested that the stack-coke product from the furnaces at the Creole refinery at Carapito may be of interest, and this too, should be added to any list of proposed radiometric examinations.

Coal deposits near Coro, State of Falcón

Abstract

Lignite in the Cerro Pelado formation of lower Miocene age was examined radiometrically in two areas near Coro, State of Falcón. Neither the lignite and enclosing shales and sandstones of the Cerro Pelado formation, nor the lower part of the overlying Socorro formation and the upper part of the underlying Agua Caliente formation were appreciably radioactive. Another coal examined near Jacura was also not detectably radioactive. Although the non-radioactivity of the rocks examined suggests that further search for uranium in the area is probably not warranted, if other geologic work in this, or in any other coal-bearing region in the country is done, coals should be examined for radioactivity.

Introduction

Because some lignites of Tertiary age are uraniferous, lignites were included on the agenda of radiometric examinations in Venezuela. Two lignitiferous areas were examined near Coro, State of Falcón, on August 26 and 27, 1951 (fig. 6): the Mina de Coro area about 9 kilometers southwest of Coro; and the Carbón de Isiro area near Caujarao, about 5 kilometers south of Coro. Another coal deposit was examined briefly near Jacura, some 130 kilometers east of Coro (fig. 6).

Coal has been mined from both areas but, to judge by the caved mine openings, not in recent years. The geology of the area has been described by Weidenmayer (34) and Liddle (23), and some detailed maps have been prepared but not published by several oil companies. Formation names are those used by González de Juana (35).

Geology

The areas examined are in foothills between the coastal plain and the higher mountains to the south. The foothills are composed of folded and faulted Pliocene, Miocene, and Oligocene shales, sandstones, marls, limestone, and lignite. The dominant structural trend of beds, folds, and faults is eastnortheast. The stratigraphic section examined comprises the Socorro formation of mid-Miocene age, the Cerro Pelado formation of lower Miocene age, and the Agua Clara formation of Oligocene age (35). The Socorro formation is composed predominantly of dark gray-brown shale with some marl and sandstone beds near the base. The Cerro Pelado formation is composed of alternating thick beds of buff, carbonaceous sandstone and brown to ocherous shale with a few beds of lignite. The Agua Clara formation is a dark gray-brown shale and marl unit.

The Mina de Coro area (fig. 7), is structurally an anticline, modified by thrust and some normal faults, with older rocks exposed in the core of the fold. One bed of lignite, at least 3 feet thick, is poorly exposed.

The Carbón de Isiro area is very similar, but thrust faults have displaced the northern limb of the anticline. At least two beds of lignite are exposed; one near the base of the Cerro Pelado formation is about 1.5 feet (0.45 meter) thick, and the other, near the top, is at least 3 feet (1 meter) thick.

Radioactivity

In the Minas de Coro area radiometric traverses were made from the Agua Clara formation, across the carbonaceous Cerro Pelado formation, and into the Socorro formation (fig. 7). In the traverses each exposed bed was examined radiometrically, and the lignite was examined especially closely both in outcrop and in the dumps of old adits. None of the rocks were found to be appreciably radioactive; the arithmetic average of 10 observations taken of individual beds, during the traverse is 0.4 - 2.4; $\overline{1.3}$ (G, B). Gray shale of the Agua Clara formation stained brown by jarosite (?) contains about twice the radioactivity of the other rocks but even so, is very low in radioactivity and has no economic significance.

In the Carbón de Isiro area, radiometric traverses and bed by bed observations were made of the upper part of the Agua Clara formation, and the whole of the Cerro Pelado formation. The average of 11 observations taken of individual beds during the traverse is only 0.5 - 2.0; $\overline{1.4}$ (G, B).

Near Jacura, a brown flaky lignite about half a meter thick within maroon and brown shales of probable Miocene age is exposed along the road. Neither the lignite nor the enclosing shales were appreciably radioactive.

Conclusions and recommendations

The lignite and enclosing rocks of the Cerro Pelado formation, and those parts of the Agua Clara and Socorro formations examined in the Coro region, Falcón are not appreciably radioactive, and no intensive search for uranium in the region seems warranted. If, however, geologic work is done in this or any other area containing coal, it would be desirable to examine the coals for radioactivity.

Black sand at La Vela, State of Falcón

At La Vela beach, 15 kilometers northeast of Coro, State of Falcón (figs. 5, 6) some sparse thin patches of black sand have been concentrated by wave action. The patches are commonly a few millimeters thick, as much as 1.5 meters long, and a fraction of a meter wide. A sample of this black sand, taken for radiometric and petrographic analysis, contains 0.003 percent equivalent uranium. Under the microscope the sand is seen to be composed predominantly of rounded grains of magnetite and fragments of quartz, with abundant colorless euhedral crystals of zircon, and less abundant pink angular grains of garnet. A few grains of rutile, amphibole, staurolite, and epidote were seen.

The available quantity of the radioactive black sand is small and the radioactivity slight. The presence of zircon suggests, however, that a study of heavy mineral concentrations in beach sands along the Caribbean coast might disclose areas of greater concentration of this and perhaps, other radioactive minerals.

Copper Deposits of Aroa, State of Yaracuy

The copper deposits of Aroa, which are on the northwestern flank of the densely forested Aroa range, in the State of Yaracuy (figs. 1, 2), have been exploited intermittently from 1605 to 1932 [(36), no. 56, p. 14], and total production has been estimated [(36), no. 57, p. 45] as 1,550,000 metric tons of partly concentrated ore containing about 8.4 percent copper, and 76,987 metric tons of matte containing an unknown but higher copper content. Five mines and prospects are known in the area; San Antonio prospect, Aroa mine, North Aroa mine, Zanjón Verde prospect, and Titiara (including North Titiara) mine. The deposits, which may be reached only by the narrow-gauge railway that connects Barquisimeto with Tucacas and Puerto Cabello, were examined radiometrically on September 28, 1951.

The geology of the area has been mentioned, among others, by Liddle (23), and Miller and Singewald (37), but by far the most complete work to date is that of López, Davey and Rúbio (36), who studied the surficial geology of the area, made petrographic examinations of ore specimens that were obtained from the dumps of the inaccessible mines, and collated mine maps and historical data from company files.

The deposits, according to López, et al. (36), are in a metamorphosed limestone within a bedded sequence of graphitic calcareous schists and mica-schists that constitute the regional country rock. The rocks are probably equivalents of some of the metamorphic rocks of the Caracas region as mapped by Dengo (19), and although no exact correlation has yet been made, they are probably Cretaceous in age. The lens-shaped deposits, according to Lopez et al., [(36), no. 56, pp. 14, 15] are alined within a zone some 500 meters wide and 5½ kilometers long that trends northward. Ore minerals were determined to be pyrite, chalcopyrite, very sparse sphalerite and galena with some spots of bornite and covellite, in a gangue composed of quartz, zoisite, clinozoisite, microcline, and sericite. In contrast to the country rock the ore is unmetamorphosed (36, p. 53), and apparently of hydrothermal origin, although the nearest outcrops of igneous rocks are respectively 12 kilometers to the north-northwest, and 16 kilometers to the southwest (36, fig. 2). The average copper content of the ore is difficult to determine but may have ranged from 1.5 to 10 percent in sulfide ore and from 5 to 14 percent in oxide ore (36, no. 57, pp. 51, 65; no. 56, p. 61), Data on the size of the deposits are also inconclusive although some ore shoots are apparently from 1.5 to 8.5 meters thick (idem).

Radiometric observations were made of the smelter slag, dumps and ore piles of the Aroa mine, of water issuing from the caved portal of the Holman crosscut, and of the calcareous green mica-schist, and schistose graphitic limestone along the road from Aroa to the mine workings. No variation above the normal background level of radioactivity, that is, 0 - 3; $\overline{1.5}$ (B), was noted, and it is concluded that the rocks and ore at Aroa, and probably of the other mines and deposits in the Aroa area, are not appreciably radioactive.

Guarico galena prospect, State of Lara

One of the few occurrences of galena in Venezuela is reported from the vicinity of Guarico in the southern part of Lara by Davey (38). Davey states: "a small vein of cupriferous galena was found some years ago on the west side of La Quebrada de Lima, opposite the town of Guarico. This veinlet containing quartz, galena, and some chalcopyrite, occurs in a fossiliferous conglomeratic limestone bed. A heavy fall of ground has now buried all trace of the vein and the old workings. This occurrence appears to be very small, and while others are said to occur... (near by)...none is of economic importance. One sample of the ore assayed 33.10 percent Pb, 2.60 percent Cu, and contained traces of silver, but no gold."

We examined the locality on September 29 and on October 19, 1951, making a radiometric traverse across the area while in search of the site of the prospect, examining specimens, and interviewing local residents. The prospect site, now thoroughly obscured by landslides and vegetation, is about half a mile northwest of Guarico on the northwest side of the Chabasquén river. The country rock, judging from float boulders, appears to be brown, calcareous sandstone, and brown limestone of Tertiary age (fig. 8) overlying green schist of probable Paleozoic age. The deposit is at the northwest end of a long spur of metamorphic and igneous rock that represents the core of the Mérida Andes.

The radioactivity of all of the rocks examined and traversed was not appreciable, ranging from 0 to 1.5, and averaging 0.75 scale divisions. Specimens of galena and chalcopyrite previously obtained from float boulders by local residents were also not detectably radioactive, although some of the soil covering the hills above the prospect was slightly more radioactive (2 - 3.5; $\overline{2.5}$). One of the local guides stated that the prospect has been known, but unexploited, since Colonial times, (1600's) and that when the pits were made in 1943, the ore minerals were found in rounded boulders.

It is concluded that the deposit is not appreciably radioactive, but that any other known or newly discovered deposits of similar type in the region should be examined for radioactivity.

Sedimentary rocks between Barquisimeto and Carora, State of Lara

While en route to the Chejendé area, State of Trujillo, the opportunity was taken to examine radiometrically some of the other sedimentary rocks that are well-exposed in this desert region along the road between Barquisimeto and the vicinity of Carora, in the State of Lara (figs. 2, 8). The five localities examined are: 1) 39, 2) 47 kilometers southwest of Barquisimeto 3) at the río Tucuyo bridge, 4) near Aregüe, and 5) about 3 kilometers south of Carora.

In general (fig. 8), the rocks of this part of Lara are gray shales and limestones of Tertiary and Cretaceous age that have been gently folded and faulted. The axial trace of folds and the trace of the faults trend northeastward parallel to the general trend of the structural elements in the Andes farther southwest.

In a canyon along the road 39 kilometers southwest of Barquisimeto, black flaggy, shaly limestone and interbedded platy calcareous shale is well exposed. The rock contains many veinlets of white calcite, and some beds of black chert. It was tentatively identified in the field as part of the Colón formation of Cretaceous age, and is not appreciably radioactive; 0 - 3; $\overline{2}$, (G,B).

On a ridge about 47 kilometers by road southwest of Barquisimeto, dark gray shale is well exposed. The shale, which is probably of Tertiary age, is thin-bedded, platy, and not appreciably radioactive; 0 - 3.5; $\overline{2.5}$ (G,B).

About 75 kilometers southwest of Barquisimeto the road bridges the río Tocuyo. Along the river bank rocks are well exposed that according to Smith and Bushman (39) are typical of the Colón formation. The rocks strike in general north and dip from a few degrees to 45° W. Within a stratigraphic interval of about 400 feet (120 meters) they consist for the most part of thin-bedded dark gray to olive-green shale and silty shale, with some intercalated beds of buff calcareous sandstone as much as 8 centimeters thick. Stratigraphically above the shales is a reddish-buff quartzitic sandstone bed at least 10 meters thick. The radioactivity observed in traversing the section was not appreciable; 0 - 3; $\overline{2}$, (G, B).

We attempted to reach the cinnabar deposit of San Jacinto south of Carora but the road past Aregüe was impassable. Between Aregüe and Carora the road is laid out over splintery dark-gray to olive-green shale and intercalated inch-thick beds of brown quartzite. These rocks are probably part of the Misoa-Trujillo formation of Eocene age. Their radioactivity is not appreciable; 0 - 3; $\overline{1.5}$ (G).

About 3 kilometers south of Carora, rocks similar to those at Aregüe were examined. The rocks, which may also be of Eocene age, consist of gray or maroon micaceous slaty shale that is overlain by a rubble of quartzite boulders. The brown quartzite contains many veinlets of milky quartz. The radioactivity observed in both rock types was subnormal; 0 - 2; $\overline{1}$, (B).

In summary, the rocks of Tertiary and Cretaceous age examined cursorily between Barquisimeto and Carora, State of Lara, are not appreciably radioactive. A more thorough study of the rocks of the region would be desirable, especially of the basal beds of the Colón formation that are radioactive in the Chejendé area, State of Trujillo.

Some sedimentary rocks in the Chejendé area, State of Trujillo

Abstract

The Chejendé area in the northern foothills of the Andean Cordillera, in the State of Trujillo, was examined radiometrically in October 1951.

Except for the "light shale horizon" at the base of the Colón formation of Upper Cretaceous age, none of the other rocks examined were appreciably radioactive: quartzites of the Tomón formation (lower Cretaceous), marls, limestone and black shales of the Cogollo and La Luna formations (mid-Cretaceous), black shales of the Colón formation (upper Cretaceous), and shales, sandstones, and limestones of the Ranchería and Valle Hondo formations (Paleocene to mid-Eocene). The "light shale horizon", a bed about 2 meters thick of pale-weathering, dark brown crenulated silty clay containing abundant plant and phosphatic fish remains, is appreciably radioactive, and samples of the bed contain an average of 0.006 percent equivalent uranium, and 0.005 percent uranium. In addition to uranium, samples contain an appreciable amount of other metals.

The bed is somewhat similar to the Phosphoria formation in the United States of America in organic-, phosphatic-, uranium-, and other metal-content, and may be considered as a potentially large low-grade uranium deposit requiring additional study.

Introduction

Some of the sedimentary rocks in the Chejendé area, State of Trujillo (fig. 9) were examined for radioactivity and sampled on October 5 and 6, 1951. Samples were analyzed radiometrically, chemically, and spectrographically in the Trace Elements Section Washington Laboratory of the U. S. Geological Survey. The area was selected because available maps and reports by Smith and Bushman (39) suggested that good exposures of Cretaceous rocks could be found. A further incentive was the "light shale" bed at the base of the Colón shale that, according to the report of Sálvador (40), resembles somewhat the radioactive "fish scale" bed at the base of La Luna formation in western Zulia, and therefore might also be radioactive.

Chejendé and Ranchería are small villages in the northern foothills of the main Andean cordillera at an altitude of about 1000 meters (3330 feet). They may be reached over about 8 and 6 kilometers, respectively, of good graded road from its junction with the main Trans-Andean highway in the gorge of the Carache River about 1 kilometer below the Casa de Zinc (fig. 10). The area is one of moderate relief, and although the steep hills have been intensively cultivated, exposures for the most part, are confined to ridges and road cuts. The most detailed geologic study of the area has been made by Sálvador (40), although reconnaissance was made by Tomalin (41) prior to Sálvador's study.

Geology and radioactivity

All of the rocks in the Chejendé area are sedimentary, and range in age from Triassic-Jurassic (?) to Recent. The stratigraphic succession is tabulated below:

Table 3.--Stratigraphy, Chejendé area [after Sálvador, (40)]

Age	Group or formation	Thickness and Lithology
Quaternary		
Recent	Alluvium	Unconcolidated silt, sand, and boulders
Pleistocene (?)	River terraces	50 meters thick, silt, sand, and pebbles
	Monay Boulder beds	100 meters thick, boulders of quartzite sandstones
	Unconformity	
Tertiary		
Miocene (?)	Tamiache formation	250 meters thick, poorly consolidated pale sandstone, sandy shales, and mottled clays
	Unknown contact--probably unconformable	
Upper Eocene	Paují formation	230 + meters thick, dark gray to black fissile shale with some thin beds of black limestone and siltstone
	Misoa-Trujillo Group	
	Caus formation	80 meters thick, green to reddish glauconitic silty sandstone
	Escuque formation	40-85 meters thick, pale, quartzitic sandstone
Paleocene	Ranchería-Valle Hondo formations	210 to 800 meters thick, soft, irregular sandy shales. Formations intergrade laterally
Cretaceous		
Upper	Colón formation	200 - 210 meters thick, black, fissile shale, subordinate siltstone

Table 3.--Stratigraphy, Chejendé area [after Salvador, (40)] (cont'd)

Age	Group or formation	Thickness and Lithology
	La Luna formation	150 meters thick, thin-bedded black limestone and calcareous sandy shale with discoidal concretions
Middle	Cogollo formation	30-35 meters thick, massive, light-gray, fossiliferous limestone and calcareous sandstones and shale
Lower	Tomón formation	800 + meters thick, fine to coarse-grained sandstone, sandy shale, and siltstone, irregular bedding, subordinate gray limestone
	Unconformity	
Triassic-Jurassic(?)	La Quinta formation	Unknown thickness, dark red shales, siltstones, sandstones, and conglomerate.

These rocks have been folded and faulted in such a manner that the axes of folds and the trace of faults trend predominantly northward.

Radiometric observations were made of the contact of the Tomón and Cogollo formations at La Cuchilla (A, fig. 10-A); of the Cogollo, La Luna and Colón formations at Chejendé (B, fig. 10-B); of the Cogollo, La Luna, Colón, and basal Ranchería formations at Ranchería (C, fig. 10-B); and of parts of the Valle Hondo and Colón formation near Casa de Zinc (D, fig. 10-A).

La Cuchilla (A, fig. 10-A)

At La Cuchilla, varicolored marl of the basal Cogollo formations lies conformably upon gray fine-grained quartzite of the Tomón formation. The contact is transitional through a stratigraphic interval of about 3 meters. The radioactivity of the quartzite ranged from 0 to 2.5 scale divisions, (Beta and gamma, 0.2 milliroentgen per hour position) and averaged 1.5 divisions. The radioactivity of the varicolored marls was 2 - 4; $\overline{2.5}$ (G and B).

Chejendé (B, fig. 10-B)

At Chejendé, a radiometric traverse was made across the steeply dipping beds of the upper part of the Cogollo formation stratigraphically upward through La Luna formation and into the Colón formation.

The Cogollo formation is not well exposed where examined, but the massive gray fossiliferous limestone observed is not detectably radioactive; 1 - 2.5; $\overline{1.5}$, (G).

La Luna formation, where examined, is well exposed and consists of black shales interbedded with dark gray thin-bedded limestone. At several horizons near the base of the unit discoidal concretions contain either ammonite and pelecypod fragments, masses of pyrite crystals, or no apparent extraneous material. The upper beds grade upward within a stratigraphic interval of about 2 meters into the basal beds of the Colón formation, and except for this interval are not detectably radioactive; 1 - 2.5; $\overline{1.5}$, (G). The intensity of radioactivity increases as basal Colón is neared, and the uppermost foot of La Luna, a dark-brown limy shale, ranges in radioactivity from 3 to 7; averaging 5 scale divisions (G, B). A sample, Chejendé No. 1, taken of this bed for analysis, contains 0.004 percent equivalent uranium, 0.003 percent uranium.

The basal bed of the Colón formation is here 1.5 meters thick and consists of pale-weathering soft, "punky" crenulated black to dark brown silty clay, containing abundant plant and vertebrate fossils. The radioactivity of this bed ranges from 3 to 7; averaging 5 scale divisions (G, B). Sample Chejendé No. 2, taken of the bed for analysis, contains 0.007 percent equivalent uranium, 0.005 percent uranium.

The black thin-bedded shales of the rest of the Colón formation are not appreciably radioactive; 0 - 2; $\overline{1}$, (G).

Ranchería (C, fig. 10-B)

At Ranchería a radiometric traverse was made across the moderately dipping beds of the lower part of the Ranchería formation stratigraphically downward through the Colón formation and into uppermost La Luna formation.

The Ranchería formation of Paleocene to mid-Eocene age consists of interbedded buff sandstone and dark olive-green to black shale, with some thin beds of buff silty limestone. The rock examined is not appreciably radioactive; 1 - 2.5; $\overline{2}$, (G).

The Colón formation consists predominantly of black to dark gray laminated fissile shale with narrow transition zones at top and base. Except for the basal "light shale" bed the formation is not detectably radioactive (1 - 2; $\overline{1.5}$). The basal bed, as at Chejendé, is markedly radioactive, ranging in radioactivity from 3 to 5.5 and averaging 3.5 scale divisions, gamma or beta-gamma. The bed (fig. 11) is about 2 meters thick, and comprises an irregular basal zone of pebbles, overlain by porous pale-weathering, dark brown crenulated silty clay that is packed with fish and plant remains.

The topmost bed of La Luna formation, a bed 1 foot thick of brown slightly calcareous blocky shale, is also radioactive, ranging from 2.5 to 5 scale divisions; averaging 3.5, but the radioactivity of La Luna rapidly decreases downward and 3 meters below the top of the formation the black flaggy limestone and shale is not detectably radioactive.

In a sharp bend in the road, about 30 meters east of the exposure illustrated, the rocks are cut by a zone of fractures subsidiary to a fault of northwest trend (fig. 10-B). In some of these fractures the radioactivity ranges from 5 to 7; and averages 6 scale divisions.

Three samples were taken for analysis. Sample Ranchería No. 1, a 2-foot channel across this 10-inch vertical fracture zone, consists of dark brown blocky limy shale. The sample contains 0.006 percent equivalent uranium, 0.004 percent uranium. Sample Ranchería No. 2, a 1.5-foot channel sample, was cut across the uppermost brown calcareous blocky shale of La Luna formation. The sample contains 0.003 percent equivalent uranium and 0.002 percent uranium. Sample Ranchería No. 3, is a 6-foot channel sample cut across the "light shale" bed of the basal Colón formation. The sample contains 0.005 percent equivalent uranium, and 0.004 percent uranium.

Casa de Zinc (D, fig. 10-A)

From Casa de Zinc, a radiometric traverse was made westward along the Curvas de Coromoto toward Valle Hondo. The rocks exposed west of Casa de Zinc are part of the Valle Hondo formation of Paleocene age and consist of shale, marl, and limestone. The thin-bedded shale is dark gray, in part bleached white, or pink to maroon where marly. The limestone is buff hard evenly-bedded, and in part, sandy. The radioactivity is 1 - 2; 1.5, (G), although that of the shales and marl may be slightly greater, 1 - 3; 2, (G).

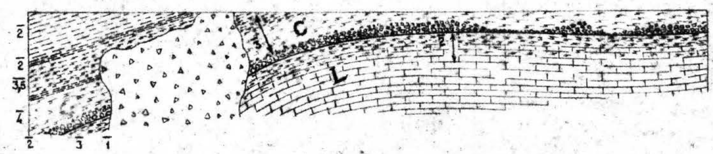
The radioactive bed

The "light shale" bed at the base of the Colón formation was first described in the Chejendé area by Tomalin (41, p. 15), who placed the bed in uppermost La Luna. Sálvador (40, pp. 86-90), because of lithology, as well as time considerations, places the bed in the basal Colón formation. He notes its similarity with the phosphatic glauconitic zone described by Hedberg (42), at the base of the Colón that extends over most of western Venezuela and northeastern Columbia. Sálvador notes that in places the bed is from 2 to 4 meters thick. The bed, because of the abundance of fish and plant remains and relative scarcity of clastics has been thought, by most geologists familiar with it, to represent the products of condensed deposition during a long static period. The bed is, therefore, both in this respect, and in its high phosphate content somewhat similar to the Phosphoria formation of Permian age of Utah, Idaho,

United States
Department of the Interior
Geological Survey

En colaboración con la Dirección de Geología
Ministerio de Minas e Hidrocarburos
Estados Unidos de Venezuela

Figura 11



LEYENDA		EXPLANATION
Talud Cuaternario		Quaternary talus
Formacion Colon	C	Colon Formation
Lutita negra		Black shale
Lutita limosa marrón con fragmentos de huesos		Brown silty shale with bone fragments.
Conglomerado		Conglomerate
Formación La Luna	L	La Luna Formation
Lutita limosa marrón		Brown silty shale
Caliza limosa marrón en capas delgadas		Brown platy silty limestone
Caliza negra en capas delgadas		Black flaggy limestone
Muestra Nº 2	2	Sample 2
Promedio de radioactividad en el afloramiento	$\bar{2}$	Average radioactivity at outcrop

Croquis del contacto entre las formaciones Colon y La Luna

Rancheria, ESTADO TRUJILLO

Sketch of the contact between Colon and La Luna formations

Rancheria, STATE OF TRUJILLO

Escala aproximada

0 1 2 3 4 5 M.

Approximate scale

F.E.J.D.

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and Wyoming. McKelvey and Nelson (15) have suggested that the uranium content of the Phosphoria may be due to physical-chemical reactions, possibly related to organisms, taking place in favorable marine environments over a long period of time.

The analyses indicate an average content of about 0.006 percent equivalent uranium and 0.005 percent uranium, over a width of about 6 feet (1.8 meters). The small but uniform preponderance of equivalent uranium over chemically determined uranium, suggests that uranium has been leached from the rock, and therefore, that the unweathered rock contains more uranium. The phosphatic fragments are probably composed of the iron phosphate, vivianite.

Semiquantitative spectrographic analyses of the samples show an appreciable metal content, in addition to the expected aluminum and silicon. All samples in the range of more than 10 percent contain aluminum and silicon; in the range from 1 to 10 percent, most samples contain calcium, iron, phosphorus, and potassium; in the range from 0.1 to 1.0 percent, most samples contain sodium, magnesium, and titanium (Sample Chejendé 1 contains, in addition to these, vanadium, barium, and nickel); in the range from 0.01 to 0.1 percent, all samples contain strontium, chromium, scandium, lead, and yttrium, and with the exception of sample Chejendé 1, above, vanadium, barium, and nickel; copper, zinc, cobalt, and zirconium are present in some samples. In the ranges below 0.01 percent, the samples contain gadolinium, manganese, lanthanum, molybdenum, boron, beryllium, and ytterbium.

Summary and recommendations

In the Chejendé area, the lower part of the Ranchería and Valle Hondo formations, the Colón, La Luna, and the upper part of the Cogollo formation, and the contact of the Cogollo with the Tomón formations were examined radiometrically. With the exception of the "light shale" bed at the base of the Colón formation none of the rocks examined were appreciably radioactive. The "light shale" bed, however, is markedly radioactive, ranging from 2 to 4 times the local background level of radioactivity. Samples thought to be representative of the weathered outcrop contain an average of 0.006 percent equivalent uranium, and 0.005 percent uranium. This bed is about 2 meters thick, and although observed only in two places, probably underlies a large area and thus offers the promise of a large low-grade uranium deposit. Preliminary spectrographic analyses indicate an appreciable content of other metals.

It is recommended that the bed be traced and sampled within the Chejendé area, and that further study be made to obtain unweathered samples of the radioactive bed that have not been leached of uranium. Satisfactory samples could be obtained either by shallow core-drilling or by test pitting. The samples should be analyzed spectrographically for rare metals, and the analyses checked by chemical analyses.

Radioactive shaly limestone in the western part of the State of Zulia

Gamma-ray logs of wells in several of the oil fields of western Zulia show a peak in gamma intensity in uppermost La Luna formation. During the field examination in October, samples of the radioactive zone were taken from drill cores in two wells, one in the Mara and one in La Paz field, as well as from the outcrop at the type section in the Quebrada La Luna. Oil seeps at La Paz field and in Quebrada La Luna were also checked radiometrically.

Principal references to the geology of the region are the papers by Hedberg and Sass (43), Sutton (44), Schaub (45), and the staff of the Shell Caribbean Petroleum Company (46).

Geology

The general geology of western Zulia, a part of the Maracaibo basin, is fairly well known; the disadvantages of thick vegetal cover in the surrounding mountains and of thick alluvium and water in the central part of the basin are offset by the amount of surface and subsurface geologic work done under the economic spur of the rich oil fields.

The rocks in western Zulia range in age from Paleozoic to Recent, and include both a thick sedimentary series as well as several types of igneous and metamorphic rocks. In general, the pre-Jurassic rocks (including most, if not all of the igneous and metamorphic types) are considered as "basement" by the oil companies, and little is known of them, and consequently of pre-Jurassic history. In contrast, the general history since the Jurassic is well known, and includes several periods of orogeny or epeirogeny, subaerial erosion and deposition, followed by marine invasion, deposition, and withdrawal.

Of concern in this report are the marine invasion and regression in the Cretaceous period during which time the Cogollo (Capacho), La Luna, and overlying Colón formations were successively deposited; and the folding and faulting that took place in the Mio-Pliocene epochs, forming the anticlines that are now the sites of the oil fields of Mara, La Paz, La Concepción, and others.

During the advance of the Cretaceous sea, the light gray thick-bedded highly megafossiliferous limestones of the Cogollo (Capacho) formation were deposited. At the maximum extent of the sea, the dark gray to black flaggy bituminous moderately fossiliferous, nodular limestones and shales of La Luna formation were deposited. In the shallower retreating Cretaceous sea, the black thin-bedded foraminiferal shales of the Colón formation were deposited. The boundary between La Luna and the Colón formations is sharp and marked by either glauconite, glauconitic limestone, or some sand, as in the entire western edge of the Maracaibo basin, (45), pp. 216, 217 ; or the boundary is marked by phosphatic thin-bedded, shaly limestone such as the "fish bone" beds in the State of Trujillo southeast of the basin (40). At Chejendé, State of Trujillo, this zone is radioactive. Basal La Luna in the eastern Zulia region resembles in general appearance, and also in radioactivity, the "fish bone" bed at the top of the formation in Trujillo.

The diastrophism of Mio-Pliocene age blocked out the Mérida Andes and the Perijá Range and probably caused most of the folding and faulting that formed the present anticlines of La Paz, Tetones, La Concepción, and others (fig. 2), upon which are now located the enormously productive oil fields of La Paz, Mara, La Concepción, San Ignacio, and others. The oil fields are similar in that they are faulted domes with the axial traces and the strike of most of the faults trending north to northeast. Their general internal relations are represented in figure 12 of La Paz field.

Sutton [(44), pp. 1715, 1722] states that La Paz anticline was first prospected because of the oil and asphalt seeps in the Tertiary rocks around it and some oil has been produced from the Tertiary rocks in these fields; but most of the oil has been produced from faulted and fractured zones in the Cretaceous rocks, especially La Luna formation.

Radioactivity

Gamma-ray logs examined from western Zulia show a consistent peak at the stratigraphic level of the basal La Luna formation. The intensity of the peak varies from well to well but is about equal in intensity to that shown in logs of the Chattanooga shale in the United States of America. Two wells, Rama 1 (Texaco) in the Mara field, and P-114 (Shell) in the southwestern part of La Paz field had recently been cored, and then gamma-logged before casing.

Rama-1 well

The gamma-ray log of Rama-1 shows a peak in gamma intensity of 8.9 inches, from the instrument zero, at a well depth of 8,433 feet. The base of the peak extends from well depths of 8,420 to 8,440 feet, or 20 ft. above the top of the Cogollo (Capacho) formation. The log was run by the Petrotec Company at a sensitivity scale of 4.5 inches. For comparison purposes Gott and Hill (47) have found it convenient to recalculate the inches of deflection to what they would be at a sensitivity scale of 10 inches. The proportion is direct and the calculation is as follows:

$$\frac{8.9 \text{ inches deflection}}{x \text{ inches deflection}} = \frac{4.5 \text{ inch sensitivity scale}}{10 \text{ inch sensitivity scale}}$$

x = 19.8 inches at a 10 inch sensitivity scale.

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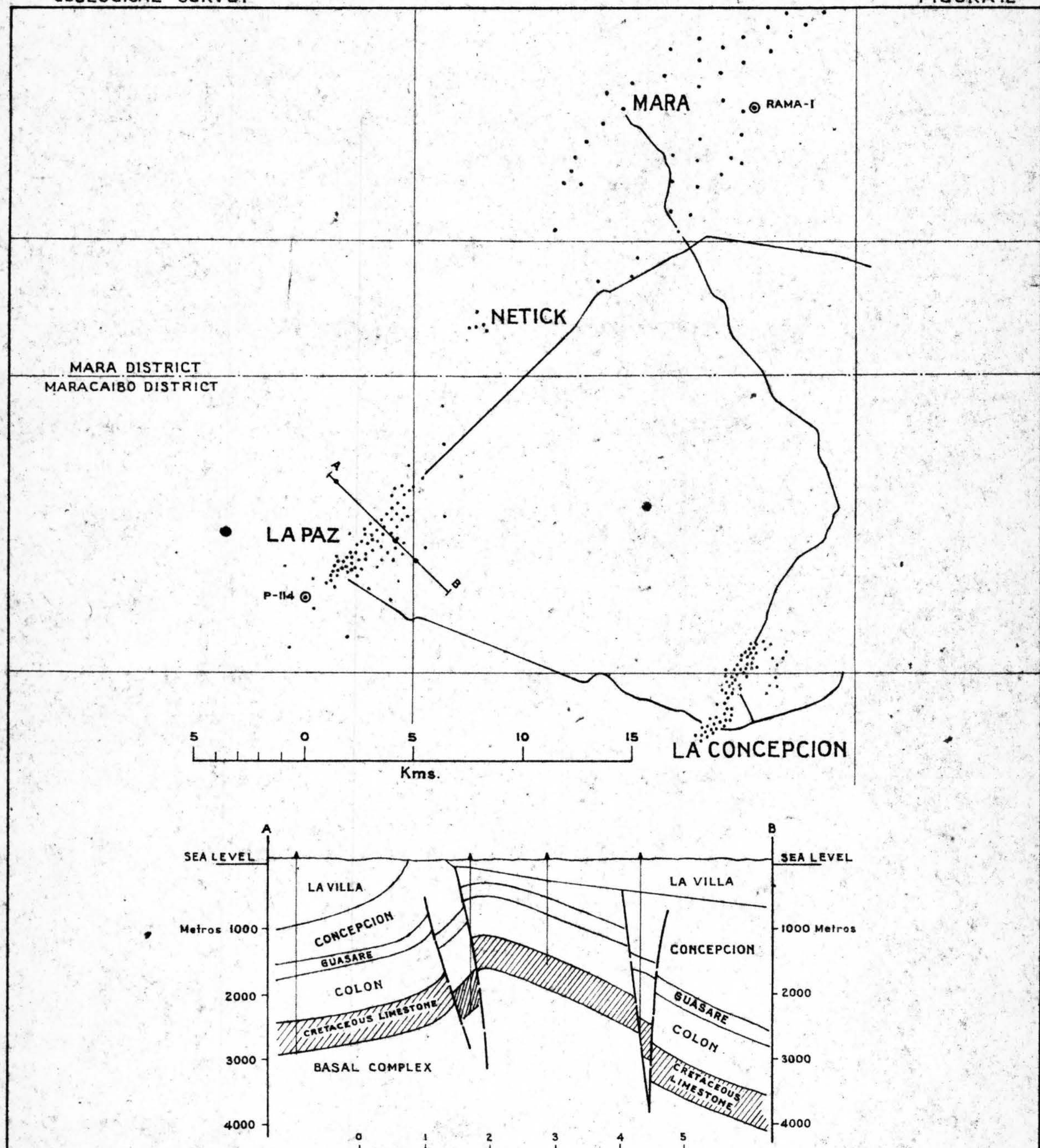
GEOLOGICAL SURVEY

FIGURA 12



MAPA DE UBICACION DE LOS CAMPOS LA PAZ, NETICK, MARA Y LA CONCEPCION, Y CORTE ESTRUCTURAL DE LA SECCION A-B, CAMPO LA PAZ, EDO. ZULIA

WELL-LOCATION MAP OF LA PAZ, NETICK, MARA, AND LA CONCEPCION FIELDS, AND STRUCTURAL CROSS SECTION A-B, LA PAZ FIELD, STATE OF ZULIA

Según Mencher y otros 1951
After Mencher, et al 1951

R. del C.

As explained elsewhere in this report, this figure can be converted to approximate percent equivalent uranium. If the approximate figure of 0.0007 percent equivalent uranium determined by Gott and Hill for each inch of deflection on the 10-inch sensitivity scale may be applied here, the core should contain a maximum of about 0.014 percent equivalent uranium. The maximum content determined by analyses is 0.012 percent equivalent uranium. Core samples, tabulated below (table 4) were taken between well depths of 8,421 and 8,439. Within this interval the rock consists of irregularly banded dark gray, in part recrystallized, limestone and black calcareous shale, containing varying amounts of fossil bone fragments. The bone fragments are as much as 6 millimeters (1/4 inch) in diameter and are conspicuous by their blue-black color, possibly caused by the iron phosphate, vivianite. Also present are thin films of macerated plant fragments. The cores were examined radiometrically with the field Geiger counter, and samples were split from the core for analysis (table 4).

Table 4.--Core samples, Texaco well Rama-1, Mara Field, Zulia

Sample No.	Well depth (feet)	Equivalent uranium (percent) 1/	Uranium (percent) 1/	Remarks
R-1-1	8421.0 to 22.0	0.003	0.002	Black laminated shaly limestone
R-1-2	8422.0 to 23.0	.002	.003	
R-1-3	8423.7 to 23.8	.001	.001	Dense gray limestone
R-1-4	8425.3 to 26.4	.004	.003	
R-1-5	8426.4 to 28.0	.002	.001	
R-1-6	8428.0 to 29.0	.004	.004	Black, laminted calcareous shale; fish bone fragments
R-1-7	8429.1 to 29.6	.005	.004	
R-1-8	8429.6 to 30.8	.005	.004	
R-1-9	8430.8 to 31.3	.006	.005	
R-1-10	8431.3 to 31.8	.001	.001	
R-1-11	8431.8 to 33.1	.009	.008	Fish bones, and carbonized plant fragments in black shale
R-1-12	8433.1 to 34.2	.001	.001	Banded, gray limestone

Table 4.--Core samples, Texaco well Rama-1, Mara Field, Zulia (cont'd)

Sample No.	Well depth (feet)	Equivalent uranium (percent) 1/	Uranium (percent) 1/	Remarks
R-1-13	8434.2 to 34.8	.005	.004	Fish bones and plant fragments in black calcareous shale
R-1-14	8434.8 to 35.2	.001	.001	Banded, gray sandy limestone
R-1-15	8435.2 to 35.9	.002	.002	
R-1-16	8435.9 to 36.8	.003	.003	
R-1-17	8437.0 to 37.4	.011 2/	.007 2/	Fish bones, black shale
R-1-18	8438.7 to 39.0	.006	.004	Fish bone bed, gray shaly limestone

1/ Analyzed in the Trace Elements Section Washington Laboratory, U. S. Geological Survey.
2/ Average of two analyses.

P-114 well

The gamma log of Shell well P-114, La Paz field, shows a peak in gamma intensity extending from well depths of 9,168 to 9,183 feet, or for 15 feet above the top of the Cogollo formation. Because a zero point is not shown on the log, no exact measurement of total inches of deflection can be made and consequently the approximate radioactivity cannot be calculated 1/.

1/ Jay Beaver, Petrotec Co., reports the log O, by comparison with other logs, gives an approximate peak of 14.5 inches at a sensitivity scale of 7.5 inches. This would be 19.3 inches deflection at a sensitivity scale of 10 inches, or about 0.013 percent equivalent uranium.

By comparison, howver, the radioactivity is probably roughly the same as that in the Rama-1 well, or about 0.01 percent equivalent uranium. Samples, tabulated below (table 4-A) were taken for analysis. The rock is similar to that in Rama-1 well, but there are less phosphatized bone fragments and more carbonaceous films. The highest radioactivity determined with the field Geiger counter is 6 - 9; 7.5 (B), in black laminated shaly limestone with abundant carbonaceous films and some phosphatic bone fragments in the interval 9,180 to 9,180.5 feet (well depth).

Table 4-A.--Core samples, Shell Caribbean well P-114, La Paz field, Zulia

Sample No.	Well depth (feet)	Equivalent uranium (percent) 1/	Uranium (percent) 1/	Lithology
P-114-1	9167.8 to 68.0	0.003	0.002	Represents dark gray calcareous shale
P-114-2	9175.5 to 76.1	.002	.002	Represents light gray shaly limestone
P-114-3	9172.6 to 72.8	.004	.002	Represents dark gray calcareous shale
P-114-4	9180.0 to 80.5	.030	.027	Black laminated shaly limestone with carbonized fossil fragments

1/ Analyzed in the Trace Elements Section Washington Laboratory, U. S. Geological Survey.

Outcrop of La Luna formation

The type section of La Luna formation according to Sutton (44, pp. 1648, 1649), and Liddle (23) is in the Quebrada La Luna, west of Villa de Rosario (fig. 2). The formation at this locality, strikes in general northeastward, and dips from 20 to 40 degrees SW. It is about 300 meters (984 feet) thick (44, 23), and consists of thin-bedded hard black shale and limestone with some chert; containing abundant discoidal limestone concretions. Some pyrite was observed, and also some oil blebs within ammonite fossils. The basal beds, immediately overlying the lighter gray, megafossiliferous limestones of the Cogollo (Capacho) formation are about 4.5 feet (14 meters) thick and consist of light tan thinly laminated earthy shale, with one 6-inch (15 centimeters) and two 7-inch (18 centimeters) beds of hard gray limestone in the upper foot, and a zone with more carbonaceous fragments in the lower foot. The radioactivity of La Luna formation except for the basal beds is 0 - 2.5; $\overline{1}$ (B), whereas the average radioactivity of the basal beds is 2 - 5; $\overline{3}$ (B). The highest radioactivity in the basal beds of La Luna formation was observed in the lower foot.

Two samples were taken for analysis, QLL-1 of the entire bed (4.5 feet), and QLL-2 of the lower foot. The samples analyzed in the laboratories of the United States Geological Survey, Washington, D. C., contained respectively, 0.004 and 0.008 percent equivalent uranium, and 0.004 and 0.007 percent uranium. The nearly identical equivalent uranium and uranium analyses suggest first that uranium is the only radioactive element, and second, that little if any uranium has been leached from the outcrop.

Tar (asphalt) seeps

Active tar seeps were examined at La Paz field and in the Quebrada La Luna (fig. 2). At both of these localities the tar and subsequent asphalt may be derived from Tertiary rather than from Cretaceous rocks, [(Hedberg (43), p. 79; Sutton (44), p. 1722], although the seeps in Quebrada La Luna were within La Luna formation. In neither locality, however, was radioactivity more than normal; 0 - 2; 1, (B).

Origin

The abnormal radioactivity in basal La Luna formation is probably caused by the extraction of uranium from sea water during long static periods, as postulated for the Chattanooga shale and the Phosphoria formation by McKelvey and Nelson (15), and as described for the radioactive shales of the Chejendé area, Trujillo.

Summary and recommendations

A zone of weakly to moderately radioactive shales at the base of La Luna formation of Cretaceous age is apparently widely distributed in the western part of the State of Zulia. The radioactive zone is 4.5 feet (1.4 meters) thick in the Quebrada La Luna, and 20 feet (6.1 meters) thick in the Mara field. The range in radioactivity of the samples taken within the zone is from less than 0.001 to 0.030 percent uranium. The wide range in radioactivity from bed to bed within the zone make an average figure difficult to calculate but it may approach 0.006 percent equivalent uranium, and 0.005 percent uranium. This compares to a figure of about 0.01 percent equivalent uranium determined as the maximum radioactivity from gamma-ray logs of the radioactive zone. Because of its sedimentary origin and the uniformity of the Cretaceous formations in the region, the bed is probably fairly continuous within this part of the Maracaibo basin, although more study is required to demonstrate this supposition.

Further study should be made of both surface exposures and of subsurface cores and gamma-ray logs to determine lateral extent, thickness, and grade. Parts of the horizon may be discovered that are more highly radioactive. In the study it would be highly desirable to determine the radioactivity and uranium content of the crude oil derived from La Luna formation. Additional petrologic, chemical, and spectrographic study of samples would be desirable to determine the radioactive element and its relationship with other rock components, especially carbonate, carbon, and phosphate, as well as the trace metal content.

Toas Island, northern part of the State of Zulia

Toas Island, in northern Zulia, was included on the agenda of investigations for radioactivity because many of the rocks in the nearly inaccessible Perijá Range of western Zulia are well exposed at Toas. The island may be reached by launch from San Rafaél de Moján, a village 43 kilometers north of Maracaibo. Our examination on October 4, 1951 consisted in radiometric traverses of rocks thought to be of interest. Toas is a small island about 6 kilometers long and 1 1/2 kilometers wide, the long axis of which trends eastward. The maximum relief is 115 meters, in contrast to the surrounding flat tidal lands. The island has been studied by many geologists, but so far as is known, no detailed geologic reports have been published, [Rivero, (48), Dusenbery and Mas Vall, (49)], although Liddle (23) describes some of the geologic features.

Geology

The rocks forming the island of Toas range in age from pre-Permo-Pennsylvanian to Recent, and consist of both igneous and sedimentary rocks. Granite, intruded by rhyolite and basalt dikes, of unknown but pre-Permo-Pennsylvanian age occupies the low-lying long axis, and the entire eastern end of the island (fig. 13). The granite is flanked to the north and south by small hills formed of sedimentary rocks of Permo-Pennsylvanian and younger age.

The granite, where observed, is a weathered friable rock composed of equigranular grains of quartz, orthoclase, and biotite in approximately equal proportions. The grains average about a quarter of an inch in diameter. The orthoclase is in part fresh and but little kaolinized, whereas the biotite has been largely converted to vermiculite. Magnetite, hematite, zircon, and perhaps other heavy minerals are accessory constituents as attested by thin films of black sand in gullies traversing the granite. Dikes of white, fine-grained rhyolite (?), and dark brown-weathering, black basalt (?) intruded into the granite are abundant east of El Toro (fig. 13).

Unconformably overlying the granite are a series of sedimentary rocks, listed below in order of decreasing age:

Age	Formation
Permo-Pennsylvanian	Palmarito (red beds)
Lower Cretaceous	Rio Negro (red beds)
Lower to middle Cretaceous	Cogollo (limestone)

Age	Formation
Upper Cretaceous	Colón (shale)
Eocene	Guasare (shale)
Eocene	Orocual (or Marcelina)
Eocene	Las Flores (shale)
Recent	Alluvium (and sand)

A small fault sliver of La Luna limestone (mid-Cretaceous) has been removed by quarrying.

The Palmarito formation, where observed, consists of indistinct beds of maroon to pink grit, conglomerate, and silt. Copper stains have been reported [Liddle (23), p. 223, Dallmus (30)], but some of the green stains observed may be the aluminum hydroxide, wavellite.

The Rio Negro formation, also of the "red bed" type, where observed, consists of pale pink to red arkose and shale. Exposures were too poor to observe bedding.

The Cogollo formation consists of massive dense gray-brown limestone, in part highly fossiliferous. Where traversed, the rock is fractured, and the fractures filled with white calcite.

The Colón, Guasare, and Orocual or Marcelina formations were not examined, as better and more typical exposures were said to be more readily accessible elsewhere.

Las Flores formation, where examined near the Toparo cement and tile plant (Alfarería, fig. 13) is a platy brown, maroon, or gray-green shale in fault contact with limestone of the Cogollo formation.

Structurally, the island is essentially a breached anticline or fan fold whose axis coincides with the island's topographic axis. The structural simplicity is complicated by steeply dipping strike and cross faults, of which there are more than those shown on figure 13. The strike faults, (those trending essentially eastward) may be subsidiary to the Ocoa fault zone that marks the northern limit of Cretaceous rocks in northern Zulia.

Radioactivity

A radiometric traverse was made from Taparo to Cerro Palmitas and is also shown on figure 13. The radioactivity of the sedimentary rocks is low, ranging from 1 to 2; averaging 1.5 (B) in the Cogollo and Rio Negro formations and between 1 and 4; averaging 2.5 (B) in the Palmarito formation. As was to be expected, the radioactivity of the granite is somewhat greater than that of the sedimentary rocks, ranging from 2 to 5.5; averaging 3.5 scale divisions (Beta and gamma). The radioactivity of the rhyolite is 1 - 3; 1.5 (B), and that of the basalt, 0 - 2; 0.75 (B). Although no abnormal radioactivity was detected, one sample was taken of black sand derived from the granite (point A, fig. 13) for laboratory study. The sample, analyzed in the Caracas office Dirección Técnica de Geología, contains 0.013 percent equivalent uranium. A heavy-mineral fraction examined microscopically, contains abundant magnetite, hematite, zircon, and sparse garnet.

Conclusions and recommendations

The rocks examined radiometrically on Toas Island, granite, rhyolite(?), basalt (?); the Palmarito, Rio Negro, Cogollo, Las Flores formations, and alluvium are not appreciably radioactive. Although black sands derived from the granitic rock are moderately radioactive, the sands are thought to represent the normal accessory minerals commonly present in granitic rocks and no additional search for radioactive material in the area is believed to be warranted. In so far as the rocks on Toas Island are representative of the same rocks in the Perijá Range, the same negative conclusion can be reached regarding the merit of further study of the Perijá.

Beach sands of Maracaibo, State of Zulia

While in Maracaibo, State of Zulia, we attempted, unsuccessfully, to contact Dr. Pedro Guzmán who, in a letter reported the occurrence of pitchblende and monazite sand from Lake Maracaibo.

We examined several localities along the lake shore both north of, within, and south of the city of Maracaibo (fig. 2), and took samples of micaceous dark sand at Point Agua Dulce. No abnormal radioactivity was detected in the field, and the sample, analyzed radiometrically in Caracas, contains only 0.002 percent equivalent uranium.

It is recommended that the exact location of the sands reported by Dr. Guzmán be obtained and more samples taken for analysis.

Mene Grande (Big Oil Seep), State of Zulia

Because of the possibility that oil may be a carrier of uranium [Gott, (47)] the Mene Grande (Big Oil Seep), in southeastern Zulia was examined radiometrically on October 2, 1951. The Mene Grande marks the site of the first major oil field in Venezuela that was brought into production in 1914 by the Shell Company (now Shell Caribbean Petroleum Company) (46). The field, on the southeast side of Lake Maracaibo (fig. 2), is in the State of Zulia, and the seeps are on and around a low hill just east of the road.

The geology of the area has been reported by many geologists, among them Sutton (44) and Liddle (23). Perhaps the most comprehensive discussion is that of the Shell Caribbean Petroleum Company (46), and the most recent condensed account, that by Mencher, et al. (50).

Geology and radioactivity

The Mene Grande oil field is on the south-plunging Misoa (or Mene Grande) anticline, which is bordered on the west by a well-developed zone of faulting. From north to south, therefore, the rocks exposed on the crest and immediate flanks of the anticline are progressively younger; they comprise, in order of decreasing age, the Misoa-Trujillo, Paují, and Mene Grande formations of middle Eocene age; the uncomformably overlying Isnotú and Sanalejos formations of probable Miocene age; and Pleistocene and Recent unconsolidated sediments. The Miocene rocks, in places, lie directly on the lower part of the Eocene Paují formation, and it is thought (46, p. 578) that the oil probably originated in Eocene rocks and rises to the surface through the permeable beds above or along the unconformity.

The oil seeps, therefore, are found in the Miocene rocks exposed on and around a low hill (Mene Grande hill) on the crest of the Misoa anticline. Liddle (23, pp. 596-597) states that there are "....hundreds of asphalt cones built up by surface seepages of asphaltic oil. These asphaltic cones, which vary in size from a few inches to 50 feet in diameter at the base, and up to six to eight feet in height, are actively flowing by heads; the oil thus brought to the surface gradually loses its lighter constituents, building up cones and surface flows along the hillside, forming a covering for the entire hill." At the time of our examination, however, most of the top of the hill had been bulldozed off for a mess hall and parking area, although there were many active seeps a few centimeters in diameter. The rock appeared to be a conglomerate or breccia of yellowish friable sandstone in tar matrix. On the western end of the hill, and in the flat southwest of it at the site of old well-14 (P-203), two active cones were observed; the cone at well 14 is about 5 feet high and, at its base, 20 feet in diameter.

Radiometric examinations were made on the top of the hill, around its flank, and at the two cones, but no rise in counting rate was observed, the radioactivity ranging from 1 to 2.5, and averaging 1.7 scale divisions (G) which is normal background. It is concluded, therefore, that the oil of the Mene Grande field is not appreciably radioactive.

The Venezuelan Andes, States of Trujillo, Mérida, and Táchira

Abstract

A radiometric reconnaissance was made in the Andean States of Trujillo, Mérida, and Táchira in October 1951. Data were obtained during the reconnaissance that illustrate the pronounced increase in normal counting rate with increase in altitude. Radiometric data were obtained for many of the rocks exposed.

Rocks of the following groups of formations were examined radiometrically: Iglesias group (pre-Cambrian?); Mucuchachí group (Devonian?); La Quinta formation (Tria-Jurassic); The Tomón, Cogollo, La Luna, and Mito Juan formations (Cretaceous), and the Angostura and Omuquena formations (Tertiary). Also examined were Pleistocene to Recent soils, saline lake deposits, spring deposits, and waters.

Abnormal radioactivity was observed in the uraniferous pegmatite in Quarry no. 3 of Carmén, near Mérida; in the salts, and spring waters from which the salts evaporate at the thermal springs of Las Fuentes (Agua Caliente) near Ureña; and in a hand specimen of sandstone impregnated with secondary uranium minerals reported to come from the rio Agaraveca near La Grita.

Additional study is recommended of the cupriferous "red beds" of La Quinta and the Tomón formations, especially if the deposit on the rio Agaraveca is authenticated; of phosphatic shale beds in La Luna and the Colón formations that in adjacent regions are uraniferous; and of the areas of uraniferous pegmatites, to discover new pegmatites, and possibly radioactive placer deposits derived from them.

Introduction

As part of the general search for radioactive source material in Venezuela, a brief general tour of the Andean region was made from September 29 to October 19, 1951 (fig. 1). The objectives of this reconnaissance were to obtain general radiometric data of some of the several rock types exposed, and to observe the effects of altitude on the counting rate of portable radiation meters; to examine some of the localities of known radioactivity; and to examine some of the rock types that offer some possibility of containing radioactive deposits.

The Venezuelan Andes extend from Columbia about 350 kilometers (210 miles) northeastward through the States of Táchira, Mérida, and Trujillo, and into Lara (fig. 1). Throughout this extent the Andes, above the 1000 meter (3250-foot) contour, average about 80 kilometers (48 miles) in width. They reach a maximum altitude of 5007 meters (16,423 feet) at Pico Bolívar.

The Andes are drained by streams that flow northwestward into Lake Maracaibo, or southeastward into the Apure, Arauca, and other tributaries of the Orinoco, although some of the streams flow down the axis of the mountain mass before changing course, and have carved deep canyons. In the Mérida region the mountains northwest of the Chama river are called La Sierra del Norte (or de Culata) and those southeast of the Chama are known as the Mérida Andes. The streams head in each case in high nodes called Páramos, which are from southwest to northeast: the Páramo del Zumbador that separates the Torbes and La Grita river valleys; Páramo La Negra that separates La Grita from the Mucuties and Chama rivers; and the Paramo Mucuchíes that separates the Chama, the Mototán, and the Santo Domingo River systems. Access to the Andean region is by the Simón Bolívar highway that was laid out along these main rivers and over the dividing Páramos. Localities examined radiometrically are shown on figure 2.

Principal references to the general geology of the Venezuelan Andes are the papers by Christ (51), Kehrer (27), (52), Kündig (53), Oppenheim (54), (55), Liddle (23), González de Juana (56), and Mencher et al. (50). The work of these geologists has been of the reconnaissance or compilation type, although some geologic sections have been measured.

General geology

The formations in the Venezuelan Andes (fig. 2) range in age from pre-Cambrian to Recent (Chart 1, columns E, G), and comprise granitic rocks, basic sills, pegmatites, gneisses, schists, quartzites, phyllites, slates, sandstones, limestones, shales, terrace gravels, and alluvium. In general, the eroded core of the Andes is composed of crystalline metamorphic and granitic rocks, the Iglesias group, of pre-Ordovician and probable pre-Cambrian age. Unconformably overlying this group lie younger Paleozoic formations. Unmetamorphosed sediments of Jurassic (?) to Recent age lie upon the eroded Paleozoic and older rocks along the flanks of the Andes and over its axis in the Táchira depression near Colombia. All rocks have been folded and faulted, with the direction of thrust apparently from the northwest quadrant.

Paleozoic rocks are exposed in several places but their interrelationships are poorly known at best. Among them are the Caparo formation known to be of Ordovician age, the Mucuchachí (Momboy) group whose age is pre-Carboniferous and post-Ordovician--possibly pre-dominantly Devonian, the Sabaneta formation and its correlative, the Mérida formation of upper Carboniferous age, and the Palmarito formation of Permian age. With the unexplained exception of the Caparo formation, all are regionally metamorphosed to greater or lesser degrees, and all have apparently been intruded by granitic sills, dikes, and stocks, with some consequent migmatization. The relation and age of the various intrusive masses are obscure.

Mesozoic and Cenozoic rocks form a nearly uninterrupted succession, the base of which is La Quinta formation of Triassic-Jurassic age, followed by the Tomón, Cogollo, La Luna, and Mito Juan formations of Cretaceous age. Basic sills and dikes inject La Quinta formation, and some of the Andean granites have been described by Kündig, (53, pp. 37,38) as intrusive into the Tomón formation. Rocks of Tertiary age exposed in the Táchira depression and in the Trujillo area include the Angostura, Mirador, Omuquena and Lobaterita formations of Eocene age, and the overlying Betijoque group that includes formations of Oligocene to Pliocene age. Extensive terrace deposits of Pleistocene age border the principal rivers, and Quaternary alluvium fills some of the broad valleys.

All the rocks in the Venezuelan Andes have been folded and faulted during several geologic periods. Apparently the most intense period of deformation was at the close of the Paleozoic (Hercynian orogeny), for the Mesozoic rocks are folded and faulted less than the Paleozoic, and the Cenozoic rocks least of all. The direction of stress in all periods probably was predominantly from the northwest or west as shown by the north to northeast trace of faults and axial planes of folds.

As prospective host rocks for uranium, the most important are the terrestrial cupriferous sandstones and conglomerates at the base of the Tomón formation , the phosphatic beds of La Luna formation, and the granitic intrusions with their associated uranium-bearing pegmatites. There have been only a few discoveries of metalliferous vein deposits in the Venezuelan Andes, and none of economic significance. In the sections that follow, the radiometric observations made of these and other rocks in the Andean States of Trujillo, Mérida, and Táchira will be discussed.

Radiometric observations in the State of Trujillo

In the State of Trujillo (fig. 9) the following rocks were examined for radioactivity: a black slate near Guarico; Tertiary rocks along the Boconó river south of Boconó; Paleozoic igneous and metamorphic rocks and Mesozoic sedimentary rocks along the road from Boconó to the town of Trujillo; and granitic and metamorphic rocks from La Puerta to the Mérida state line.

Along the road between Guarico and Boconó is a persistent black thin-bedded carbonaceous slate that may be a member of the Tomón or Mito Juan formation of Cretaceous age, or may be part of the undifferentiated metamorphic rocks of probable Paleozoic age (fig. 9). In any event, the rock is not appreciably radioactive, 0 - 2; $\bar{1}$ (G).

A radiometric traverse was made down the Boconó river from Boconó in an attempt to reach the gorge of the river where cupriferous conglomerate and sandstone of La Quinta formation has been reported by Dallmus (30). Although the gorge was not reached in 4½ miles, radiometric observations were made in the gray shales, brown sandstones, and sparse limestone beds of Tertiary age that are exposed along the trail. None were detectably radioactive.

Along the road from Boconó to the town of Trujillo (fig. 9), numerous radiometric observations were made in undifferentiated gneiss, schist, and the intruded granite and pegmatites that may be part of the Iglesias series of pre-Ordovician age; in the gray phyllites, slates, and quartzites of the Mucuchachí formation that may be of Devonian age; in the red sandstones and conglomerates of La Quinta formation of Tria-Jurassic age, and in buff sandstones of the Tomón formation of Cretaceous age. None of these rocks are appreciably radioactive, the range in radioactivity observed was from 1 to 3 scale divisions; and the average 2, (gamma, or gamma-beta). From 3 to 7 kilometers above Boconó, some small simple granite pegmatites contain considerable feldspar and muscovite, and in these the radioactivity was 2 - 4; $\bar{3}$ (G, B), the slightly increased average probably owing to the radioactive isotope potassium-40. Copper staining was not observed in either La Quinta or the Tomón sandstones, although the basal beds of La Quinta were probably not exposed, or were missing because of faulting.

From La Puerta to the Trujillo state line, several radiometric observations were made of granite exposed in the road cuts. The rock is a faintly banded orthoclase-biotite-quartz granite porphyry containing some orthoclase phenocrysts as much as 1 inch on an edge, and some muscovite. The radioactivity was not appreciable, 0 - 2.5; $\overline{1.5}$ (G, B).

Radiometric observations in the State of Mérida

In the State of Mérida radiometric observations (fig. 14) were made of granite, of quartzite and black slate of the Mucuchachí (?) formation between the Trujillo State line and Pico Águila, of the uraniferous pegmatites at the Carmén quarries near the city of Mérida, of the trona and gaylussite at Lake Lagunillas, of granite near Tovar, and of gneiss in the Páramo Mucuchiés.

Between the Mérida state line and Pico Águila

From the Trujillo state line to Pico Águila, one ascends from 4,500 feet (1,372 meters) to an altitude of 13,383 feet (4,081 meters), and traverses granite, alluvium, and phyllite of the Mucuchachí formation.

Radiometric data were taken at increasing altitudes here, and elsewhere in the Andean region, with a portable Berkeley scale-of-eight Geiger counter to observe the effects of altitude, and increase in cosmic ray activity, on the normal counting rate. Factors to be evaluated before a correction for cosmic radiation could be applied to any radiometric observation, made at any altitude, are the geometry of the site and the accuracy of the observation. Clearly, in a partially protected position in a canyon, the instrument would be less affected by the cascade effects of cosmic radiation than in a more exposed position. In each case the observations tabulated below (table 5) were made with the Geiger-Muller probe in the air at the outside edge of the road. Each point is an average of three or more observations. The general level of radioactivity caused only by the rock, is, of course, variable but between the points on the graph would probably range only between 50 - 60 counts per minute.

The pegmatite quarries of Carmén

The pegmatite quarries of Carmén are about 4 kilometers northeast of Mérida via the Trans-Andean highway. Pitchblende specimens from these pegmatites were the first described in Venezuela, by Davey (2, 38). The deposits have been examined for their uranium potentialities by Davey (2, 38), Worcester (12), Larson (13), Schwarck Anglade (5), and by Galavís and Dengo (57), and for their mica and beryl potentialities by López, Aguerrevere, and Davey (4). Accordingly, a detailed examination by the writers was not considered necessary, but a brief examination was made because of the widespread distribution of narrow pegmatite dikes in the Andean region.

The observed pegmatite dikes of Carmen are irregular bodies that trend in general northwestward, in fine- to medium-grained quartz-othoclase-biotite granite or granite gneiss. The pegmatites are composed essentially of quartz, orthoclase, albite (?), and muscovite with trace amounts of garnet, schorlite, and pitchblende, although zircon, pyrite, and white beryl have been reported by Vivas R. (58). In a muscovite book in Quarry no. 3, we found one cubic crystal of uraninite that measured 0.5 inches (1.2 centimeters) on an edge, and was coated with secondary uranium minerals. The dike in this quarry is about 13 feet (4 meters) wide at its widest point and at least 30 feet (9+ meters) long; it trends N. 60° W., dips about 40° north and pinches out to the southeast. Examination with the radiation meter showed a pronounced increase in radioactivity (as much as 10 scale divisions, 2.0 milliroentgen per hour sensitivity scale, (G), over the pitchblende crystal, a slight increase (as much as 6, 0.2 per hour sensitivity scale, G and B) for about 3 feet along the northeast side of the pegmatite, but no other detectable radioactivity. The background level of radioactivity at this locality and altitude (1,800 meters or 5,850 feet) was 1 - 3; $\bar{2}$, (B).

Davey reports (38, pp. 154, 155) that about 2 pounds of pitchblende had been produced prior to abandonment in 1944. It is of geologic interest to note that Davey (2) calculated the age of one specimen of pitchblende from the Carmén quarry as 948,480,000 years or middle- upper- pre-Cambrian. The lead/uranium ratio was used, following Holmes' method, with analyses by the National Laboratory, Venezuela.

Other pegmatites that contain specimen amounts of one or more of the uraniferous minerals pitchblende, columbite-tantalite, autunite-torbernite, or calcio-carnotite are those near Timotes [Davey, (2), and (38), Worcester, (12), Larson, (13), Schwarck Anglade, (5), Galavís and Dengo, (57), Lopez, et al., (4)] TABLE

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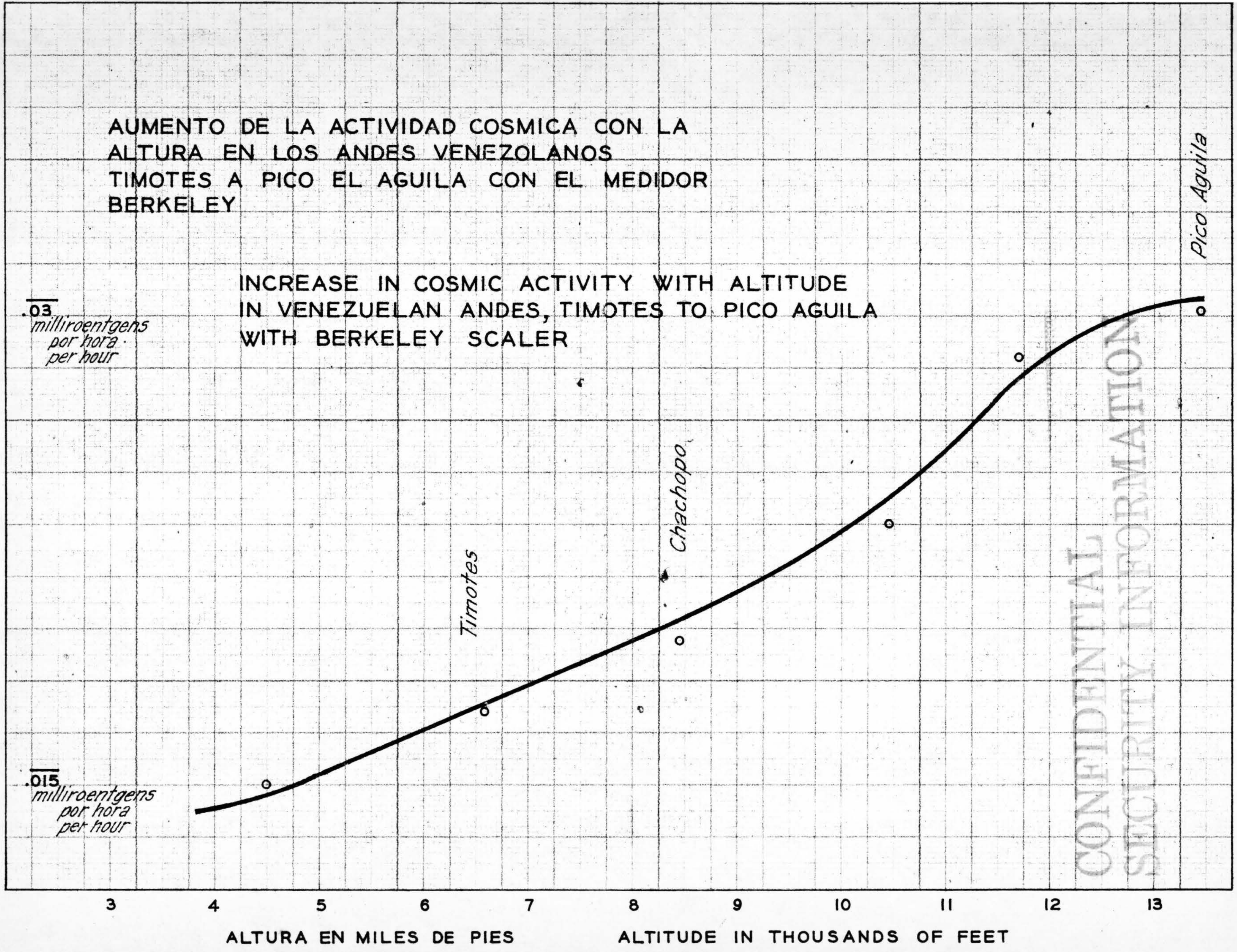

AUMENTO DE LA ACTIVIDAD COSMICA CON LA ALTURA EN LOS ANDES VENEZOLANOS TIMOTES A PICO EL AGUILA CON EL MEDIDOR BERKELEY
INCREASE IN COSMIC ACTIVITY WITH ALTITUDE IN VENEZUELAN ANDES, TIMOTES TO PICO AGUILA WITH BERKELEY SCALER
CONTAJE POR MINUTO COUNTS PER MINUTE
.03 milliroentgens por hora per hour
.015 milliroentgens por hora per hour
100
90
80
70
60
50
Timotes
Chachopo
Pico Aguila
3
4
5
6
7
8
9
10
11
12
13
ALTURA EN MILES DE PIES
ALTITUDE IN THOUSANDS OF FEET

A few more pounds of pitchblende might be produced from the quarries of Carmén, but the writers concur with Worcester, Larson, Schwarck Anglade, Galavís and Dengo that here, as in most other pegmatites in the world, no significant quantity of uranium is available.

Lagunillas Lake

Lagunillas Lake (fig. 14) is on the northwest outskirts of the town of Lagunillas. The shallow lake is in terrace deposits of Pleistocene age at the foot of the Sierra de Culata. Gaylussite ($CaCo_3 . Na_2CO_3 . 5 H_2O$), trona (urao) $Na_2CO_3 . Na H CO_3 . 2H_2O$) and natron (?) ($Na_2CO_3 . 10 H_2O$) are precipitated from the strongly alkaline water along the shores, in artificial tanks and ponds, and in beds at the bottom of the lake [Davey (38), pp. 156-157]. The salts may be derived from basic rocks injected in basal La Quinta formation a few miles to the west. Radiometric observations were made of the water, the shore mud, of the salt incrustation along the edge of the lake and in evaporation tanks, as well as of the mother liquor in the brine tanks. The radioactivity was 0 - 3; $\bar{1}$ (B,G), and therefore the materials tested are not detectably radioactive.

Tovar-Zea road

The road from Tovar to Zea crosses a granitic stock (fig. 14), the Tovar massif, that intrudes schist and gneiss and is probably part of the Iglesias group. The rock observed is a medium-grained porphyritic to equigranular quartz-orthoclase-biotite granite containing orthoclase phenocrysts as much as half an inch on an edge and some epidote and quartz-feldspar dikelets. Some xenoliths of green chlorite-muscovite schist were observed in the foliated granite. The radioactivity observed in four places ranged from 1 to 5 scale divisions and averaged 2.5, G, B, on the most sensitive scale. The rock is therefore not appreciably radioactive, nor is the alluvium that is composed largely of decomposed granite, at the southern outskirts of Tovar.

Páramo Mucuchíes

On the pass between Mucuchíes and Santo Domingo, radiometric observations were made of the granite gneiss and pegmatitic dikelets of the Iglesias group (?). The observations made with the Berkeley scale-of-eight Geiger counter averaged 93 counts per minute which would appear to indicate no abnormal radioactivity at this altitude of 11,920 feet (3,667 meters).

Las Tápias

Another area in Mérida that has previously been examined radiometrically by Schwarck Anglade (11) and Larson (13) and was not examined by the writers, is the area of Las Tápias near Bailadores (fig. 14). Here, thin stringer veinlets containing galena and chalcopyrite that are of no apparent economic significance, are not detectably radioactive (11, 13).

Radiometric observations in the State of Táchira

Radiometric observations were made in the State of Táchira along road cuts in the San Cristóbal area, at the springs of Las Fuentes (Agua Caliente) near Ureña, and in the Seboruco-La Grita area (fig. 15).

San Cristóbal area

From the Páramo Zumbador southward, the Paleozoic and pre-Paleozoic crystalline and low-grade metamorphic rocks that comprise the core of the Andes are completely covered by Cenozoic and Mesozoic sedimentary rocks, and the altitude of the ground surface concomitantly drops from over 3,000 to less than 1,000 meters into what is known as the Táchira depression.

La Quinta and the Tomón formations of Tria-Jurassic, and lower Cretaceous age, respectively, were examined near Michelena (fig. 15, no. 1), and near the Páramo Zumbador (fig. 15, no. 2).

Near Michelena.--Near Michelena, La Quinta formation (Tria-Jurassic) is in fault contact with the steeply dipping Angostura (Eocene) formation and about 800 feet of the basal part of La Quinta are probably missing according to Vivas R. (58). La Quinta formation is here a dull red thin-bedded micaceous, sandy, argillaceous siltstone. The radioactivity ranged from 1 to 2.5; and averaged 1.75 meter units, (B), and the rock is thus not detectably radioactive. The Angostura formation here consists of platy shale with subordinate beds of buff calcareous sandstone and bituminous coal. The coal bed is 2 feet (0.6 meter) thick, and evenly-bedded, with pyrite and sulfur (?) along numerous fracture surfaces. The radioactivity of the coal was 1 - 3; $\overline{2}$ (B), and may be considered negligible.

Near the Páramo Zumbador.--Near the Páramo Zumbador (fig. 15, no. 2) La Quinta formation is in normal contact with the overlying Tomón formation (Cretaceous). The beds strike North, and dip about 20°W. The upper part of La Quinta formation is here a reddish silty clay, and is deeply weathered. The overlying Tomón formation consists of white friable to moderately silicified gravel and conglomerate composed largely of rounded quartz pebbles. The rock is colored reddish by staining from the topographically higher red beds of La Quinta formation. The radioactivity of the Tomón formation was found to be 1 - 2; $\overline{1.5}$ (B), and that of La Quinta, 2 - 4; $\overline{2.5}$. The rock of both formations is, therefore, not appreciably radioactive here.

La Luna formation of Cretaceous age, that in the Chejendé and western Zulia regions contains uraniferous phosphatic shale beds near its top and base, respectively, was examined near Palmira (fig. 15, no. 3), and west of Independéncia (fig. 15, no. 4).

Near Palmira.--Near Palmira, along the road above La Blanca cement plant, limestone is quarried from steeply dipping beds of the Cogollo formation that is here in normal conformable contact stratigraphically beneath La Luna formation. The Cogollo formation, here, as elsewhere, is a dark gray highly megafossiliferous recrystallized limestone. The contact with La Luna formation is gradational and marked by thin beds of dark brown calcareous silty shale, some of which contain sparse fossil bone fragments and some of which contain pellets or blebs of asphalt rimmed by white calcite. The lower part of La Luna formation is composed of typical black dense shaly flaggy limestone containing large concretions. The middle and upper part of the formation consists of bedded black chert that at least in part replaces both shale and limestone beds. One bed 2 inches (5 centimeters) thick of buff bentonite was observed at the base of the chert. The radioactivity of all the rocks except the fossil bone beds was 1 - 2; $\overline{1.5}$, and the radioactivity of the bone beds was 1 - 3; $\overline{2}$. None of the rocks are, therefore, appreciably radioactive. The reason for the lack of radioactivity in the basal beds of La Luna formation in this region, and its presence in western Zulia is unknown, but radioactive beds may have accumulated uninterruptedly in deeper or more stagnant parts of the mid-Cretaceous sea, and nonradioactive beds may be related to the silicification that produced chert.

Coal beds in formations of Eocene age were examined on the road west of Lobatera (fig. 15, no. 5), and on the road east of San Antonio (fig. 15, no. 6).

Near Lobatera.--Across the canyon west of Lobatera near a mining camp called Cazadero, coal is mined from the Omuquena formation of upper Eocene age. The coal is in a sequence of brown shale and thin-bedded sandstone, and appears to be a glossy black woody lignite. There are at least three beds within a stratigraphic interval of about 15 feet (4.6 meters), the lowermost of which is about 6.5 feet (2 meters) thick, and the two upper beds from 6 inches to 18 inches (1.5 to 4.6 decimeters) thick. The radioactivity of the coals ranged from 1 to 3 scale divisions and averaged 1.5 (B), and that of the intervening shale ranged from 1.5 to 3 scale divisions and averaged 2, (B). These beds are, therefore, not appreciably radioactive.

East of San Antonio.--East of San Antonio (fig. 15, no. 6) the road is cut in the Angostura formation ('Third coal' of older terminology) of lower Eocene age exposing a series of steeply dipping, folded and faulted coal beds that range from 2 inches (5 centimeters) to a foot (30.5 centimeters) in thickness and that grade laterally into black carbonaceous shale. The radioactivity of 1 - 3.5; $\overline{1.5}$ (G) is not appreciable.

Springs of Las Fuentes (Agua Caliente)

The small village of Las Fuentes, (Agua Caliente) is about 2½ kilometers northeast of Ureña (fig. 15, no. 7) at the western base of the Andean foothills and the eastern edge of the low-lying plains of Ureña. The springs have been investigated chemically by Otero, Prado, and Giménez (59), and radiometrically by Cárdenas (60).

The springs, of which about 12 are named (fig. 16), issue from the face of a rubble-covered hill and flow into two quebradas before joining the Quebrada Agua Caliente. The hill is capped by thick blocky quartzitic sandstone that may be part of the Mirador formation of Eocene age according to Vivas R. (58), but no published account of the geology of the area could be found. The attitude of the thick sandstone bed is in general horizontal, whereas, that of the gray-brown platy shale and intercalated sandstone beds west of the springs are steeply inclined. Accordingly, the inference is drawn that the springs are issuing either from a fault scarp, or from a surface of unconformity. Older rocks (including La Luna and La Quinta formations) undoubtedly underlie the region. The springs issue from a number of small sources, and total flow is estimated [Otero and others, (59), p. 119] to be about 1400 cubic meters (about 367,000 gallons) daily.

Otero, and others, (idem.) divide the springs into two groups, one of low temperature with a volume of about 100 cubic meters (about 26,000 gallons) daily, and another of higher temperature with a volume of about 1300 cubic meters (about 341,000 gallons) daily. The springs in Quebrada Fria (fig. 16) are cold (59, p. 118) and nonradioactive (60), whereas the warmer springs are radioactive. The highest temperature measured by Otero, and others, was about 61° C (142° F) at Pringues, and the spring is also the most radioactive. The chemical composition, pH, and temperature of water samples from San Roque Spring and from Pringues by Otero, and others, (59, pp. 128, 129) tabulated below (table 6) show major ion components to be calcium, sodium, sulfate, and bicarbonate.

Radiometric observations were made of the spring water, mud, and the salt-incrusted sandstone cobbles at all springs from San Rafael to Kerosenadas (fig. 16). The springs Uso Domestico, the 50° spring south of it, Pringues, and the 58° and 60° springs between Pringues and Kerosenadas are the only ones that are radioactive. At the 50° spring south of Uso Domestico the radioactivity of the water was 4 - 6; $\bar{5}$ (B), but that of some of the white salt was more than $\overline{20}$ (B). At Pringues, the radioactivity of the salt-incrusted rocks below the sources of the springs was $\overline{25}$ (B), but the radioactivity gradually decreased as the counter was moved up to it, and at the source of the springs, the radioactivity was not detectably above background. The other springs, and the sandstone above the springs were not detectably radioactive (0 - 2; $\bar{1}$, B,G).

The radioactive salt incrustation, a soft botryoidal usually no more than paper-thin layer, is dominantly white although some green tints caused by moss and some black caused by manganese were observed. Specimens were taken of the radioactive white salt, and of radioactive wad. Under the microscope the salt is seen to be composed of soft (hardness of 2 to 3), colorless, platy crystals, some of which are stained with manganese oxides, the presence of which was confirmed chemically. The salt where uncontaminated does not effervesce in dilute (1 percent) HCl. The results of fluorescent spot tests for uranium using sodium fluoride-potassium carbonate flux were

Table 6.—Analyses of spring water, Las Fuentes (Agua Caliente), near Ureña by J. L. Prado [Otero and others, (59)]

Component	San Roque (milligrams/liter)	Las Pringues (milligrams/liter)
Cl^-	11.8	12.1
I^-, Br^-	Less than 0.02 mg/lt	
F^-	0.2	0.2
$SO_4^=$	137.2	95.4
$S_2O_3^=$	3.6	-
HS^-	15.0	-
HCO_3^-	150.0	167.0
PO_4^-	Less than 1 mg/lt	
$AsO_4^=$, NO_3^-	Less than 0.02 mg/lt	
NO_2^-	0.006	0.039
BO_2^-	1.0	1.5
SiO_2	27.2	29.4
Subtotal (Anions)	346.0	305.6
Na^+	52.4	42.0
K^+	5.5	5.4
Li^+	Less than 0.005 mg/lt	
Ca^{++}	60.5	49.6
Mg^{++}	8.0	5.0
Mn^{++}	0.3	0.3
$(Fe, Al)_2O_3$	2.2	6.1
Zn^{++}	Less than 1 mg/lt	
Subtotal (Cations)	128.9	108.4
Total (ions)	474.9	414.0
Total soluble salts (to 100° C)	400.2	331.5
Residue on burning	259.0	251.0
pH	7.15	7.65
Temperature	40° C	60.5° C

negative. The radioactivity of two samples of sandstone incrusted by the salt was 0.053 and 0.054 percent equivalent uranium by beta-gamma radiation, but only 0.014 and 0.012 percent equivalent uranium by gamma-radiation alone. A thin iron shield was used to screen out beta particles. For comparison, a sample of radioactive salt, incrusting schist from Las Trincheras, examined radiometrically in the same manner, contained 0.049 percent equivalent uranium (beta-gamma), and 0.014 percent equivalent uranium (gamma).

Inasmuch as the uranium spot tests were negative, and the gamma radiation is about the same as that of salts from Las Trincheras that were analyzed chemically and found to contain appreciable thorium and practically no uranium, it is concluded that the radioactivity of the salt at Agua Caliente is also caused by thorium. Accordingly the area is probably not a favorable one in which to look for uranium deposits.

Seboruco-La Grita area

La Grita is in the center of a long belt of outcrops of Paleozoic slates and phyllites of the Mucuchachí formation (fig. 15) that are flanked by Tria-Jurassic red beds and conglomerates (La Quinta formation) and overlying Cretaceous sandstones and limestones (Tomón, Cogollo, La Luna formations, etc.). Small amounts of copper have been mined from the Tomón and La Quinta formations since colonial times (1600's) according to González, M. (62). Radimetric observations were made of the basal beds of La Quinta formation and of the underlying Mucuchachí formation southwest of La Grita (fig. 15, no. 8), and of three of the small copper deposits in the basal beds of the Tomón formation near Seboruco (fig. 15, no. 9).

Near La Grita.--About 3 kilometers southwest of La Grita (fig. 15, no. 8), La Quinta formation rests unconformably upon the Mucuchachí formation. This locality is within a kilometer of the type section of La Quinta formation described by Kündig (53, pp. 32,33). Where observed, the Mucuchachí consists of green schist and phyllite that contain partly chloritized garnet crystals. The rock in the upper 20 feet (6 meters) is deeply weathered and stained red by solutions derived from the overlying red beds. The contact is a zone 5 feet (1.5 meters) thick in which large blocks of phyllite are embedded, or partly separated by red sand and silt. The basal 50 feet (15 meters) of La Quinta formation is a maroon coarse-grained sandstone, composed of grains and a few pebbles of phyllite, quartz, biotite, and sparse feldspar in a silty clay matrix. The radioactivity observed ranged from 1 to 3 scale divisions and averaged 2 (G), and the rock, therefore, is not detectably radioactive. No stains of secondary copper minerals were observed.

Near Seboruco.--Near Seboruco (fig. 15, no. 9), about 13 kilometers southwest of La Grita, copper minerals in the basal beds of the Tomón formation (lower Cretaceous) have been described by Grenouillet (61).

The beds of the conformable Tomón and La Quinta formations strike in general eastward to N. 70° E. and dip from 40° to more than 60° north to northeast. The beds in most places are obscured by thick grass and low shrubs, but crop out in stream valleys and elsewhere, if quartzitic. Of the several areas mineralized with copper minerals, three in Quebrada La Mina were examined (fig. 17, no's. 1, 2, and 3).

The deposits examined are much alike and resemble many of the sedimentary copper deposits in the Colorado Plateau area of the United States of America. The secondary copper minerals chalcanthite, azurite, and some malachite, are interstitial or coat quartz pebbles and stain fracture surfaces of conglomerate in the Tomón formation from 0 to 3.5 feet (1 meter) above La Quinta formation. Grenouillet reports (61), however, that copper minerals have been found in La Quinta and, in the Tomón, as much as 60 meters (200 feet) above its base. The mineralized zones are from 6 to 20 feet long (1.5 to 6 meters), and from a knife edge to about 3.5 feet (1 meter) thick. Although they appear to be limited vertically by cross-bedded less porous conglomerates or sandstone, the third dimension is unknown. About 90 percent of the conglomerate is rounded pebbles of vein quartz, and the rest is finer grains of quarts and feldspar and silica cement. A few fragments of carbonized wood were observed. The rock is porous, but the porosity may be caused by fracturing. The copper minerals appear to be deposited from ground water traversing permeable beds and are definitely epigenetic. The deposits were examined closely with the Geiger counter but the radioactivity observed was only 1 - 3; 2 (B,G), and thus not appreciable.

Grenouillet (61) observed bornite in some of the deposits, and it would be of interest to examine some of this "primary" sulfide radiometrically. Ore samples obtained by Vivas R. (58) in a detailed sampling project for copper in La Quinta and the Tomón formations in the Seboruco-La Grita area should be analyzed radiometrically. Some of this radiometric work has been done in the Caracas office by Sharp and Antonio Cárdenas but no samples containing more than 0.004 percent equivalent uranium have so far been found. Ore samples, however, are not at present available.

In La Grita, a specimen of fine-grained sandstone coated with tabular crystals of a yellow secondary uranium mineral that resembles schroeckingerite or autunite was shown the writers by the collector, Dr. V. S. Paulik. Dr. Paulik, who has been prospecting for copper, lead, and silver in the Seboruco-La Grita-El Cobre area, states that the specimen is from a lens about 1-inch (2.5 centimeters) thick and 20 meters (66 feet) long that occurs between sandstone and shale on the Agaraveca River, about 8 to 10 kilometers southwest of Seboruco. Lack of time prevented our examining the deposit as it is about 3 days distant by horseback from La Grita, but it was strongly recommended in a memorandum to Dr. Schwarck Anglade dated October 26, 1951, that the locality be examined by members of the Dirección Técnica de Geología, stationed in La Grita or Mérida.

Summary and conclusions

Radiometric observations were made at several places and of various rock types in the Venezuelan Andes from the State of Trujillo southwest to the State of Táchira, but radioactive minerals were observed only in the pegmatite quarry of Carmén near Mérida, at the hot springs near Ureña, and in a hand specimen of sandstone from the Agaraveca River south of Seboruco. The other rocks examined were not appreciably radioactive although the increased counting rate, attributable to greater cosmic ray activity in higher altitudes, makes radiometric work difficult.

Three rock types seen merit additional study in the Andes: the pegmatites; "fish bone" beds in La Luna formation; and the base metal-bearing conglomerate and sandstone of La Quinta and the Tomón formations. Of these three rock types, pegmatite is regarded as economically the least important, but additional search for uranium minerals in pegmatites as well as in placers derived from them certainly should be made in any geologic work done in the future. Between the Chejendé area, State of Trujillo or the western Zulia area, and the Táchira area, the radioactive "fish bone" beds or "light" shale appear to disappear. It would be advisable to trace the radioactive beds in the field as far as possible from Zulia and from Trujillo, with the hope that areas of greater radioactivity might be discovered. With this in mind, isopach and lithofacies maps of La Luna formation might also be of considerable use.

If verified in the field, the discovery of secondary uranium deposits in sandstone in such favorable terrain as the area covered by the Tomón and La Quinta formations would be of considerable significance. The formations of continental origin resemble some of the continental formations of about the same age in the United States of America from which both secondary and primary ores of uranium are being exploited. The presence of either schroeckingerite or autunite suggests that concealed deposits of primary uranium minerals may be nearby. Such deposits in the United States of America are relatively small, but of fairly high-grade. Accordingly, it is recommended that a systematic examination of all known areas containing copper, lead, or silver mineralization in these formations be started.

Chemical analyses of the radiometric salt from the spring of Agua Caliente near Ureña should be made, but if the radioactive element is found to be thorium, as is suspected, more study of the area as a potential source of uranium is not warranted.

The State of Bolívar and the Territory Delta Amacuro

Abstract

A radiometric reconnaissance was made in the State of Bolívar and at one locality in Territory Delta Amacuro in November 1951. Between Ciudad Bolívar and El Dorado, in addition to examining individual localities, a continuous record of gamma-ray activity was made along the roads traversed, by means of special radiometric equipment of high counting rate. During the reconnaissance the following rock types were examined:
1), felsic and mafic rocks of the basement complex (Archean?);
2), quartzite of the Imataca series (lower Paleozoic?, Archean?);
3), mafic volcanic rocks of the Pastora series (Cretaceous?);
4), sedimentary rocks and intrusive sills of the Roraima series (Cretaceous?). In addition, soil and alluvium of Pleistocene to Recent age were examined, as were some gold-quartz veins, some gold- and diamond-bearing placers, and some manganese and hematite deposits.

Radioactive minerals were found in porphyritic facies of banded gneiss (migmatite) of the basement complex, or in placer sands derived from them at seven separate localities along the northern edge of the Brazilian shield; radioactive minerals were also found in detrital black sand beds in the basal part of the Roraima series at Peraitepuy. Samples of these materials contain from 0.005 to 0.73 percent equivalent uranium although it is suspected that most of the radioactivity may be caused by thorium. The basic igneous rocks examined are practically devoid of radioactivity.

Additional study is warranted of the more felsic rocks of the basement complex, especially of the radioactive gneiss; of the basal beds of the Roraima series in search of both heavy mineral concentrations and uranium deposits of the "red bed" type; and of the gold and diamond placer deposits. Other gold-quartz deposits might also be studied. Where possible in the study it is recommended that isoradioactivity maps be compiled by means of carborne radiometric equipment. It is probable that the mafic igneous rocks of the region can safely be disregarded in future radiometric work.

Introduction

As part of the general search for uranium deposits in Venezuela, a brief tour of the State of Bolivar, and of a small part of the Territory Delta Amacuro was made in November 1951 (figs. 1, 2). Areas between Ciudad Bolívar and El Dorado in the State of Bolívar were reached by Jeep (fig. 18), areas south of El Dorado in the Gran Sabana were visited by airplane, and the one area examined in Territory Delta Amacuro was reached by air, boat, and foot (fig. 2).

The entire region of Venezuela south of the Orinoco river (fig. 1) is divided politically into the Territory Delta Amacuro, the State of Bolívar, and the Territory Amazonas. This region is divided topographically into the low grass and scrub-covered peneplains of the northern part of the State of Bolívar, the low-lying jungles or "selva" of the Territories of Amazonas and Delta Amacuro, and the high broad valley, savannah, and mesa uplands of the Gran Sabana that extends from the southeast corner of Venezuela southwestward into Territory Amazonas, northeastward into British Guiana, and southward for a relatively short distance into Brazil. The area is limited to the north and west by the great arc of the Orinoco river, into which drain subsidiary streams that head in the Gran Sabana.

Access to this vast sparsely populated frontier region of over 450,000 square kilometers, except for a few roads in the northern rim, is by airplane, boat, or foot.

Principal references to the geology of the region are the papers by Tate and Hitchcock (63), Tate (64), Zuloaga (65), Zuloaga and Tello B. (66), Aguerrevere, López, Delgado, and Freeman (67), López, Davey, and Rúbio (68), López, Mencher, and Brineman (69), and Liddle (23). In addition to these published accounts, current reports of local and general geology by Dengo, and others (70) are on file in the Dirección Técnica de Geología.

General geology

Geologically the region constitutes the northern part of the Brazilian Shield whose extreme northern and western limits of outcrop are neatly bounded by the Orinoco river (fig. 2). North of the Orinoco the rocks of the shield are overlain by sedimentary rocks of Tertiary age. The rocks of the Brazilian shield, exposed in the State of Bolívar and in Territory Delta Amacuro, range in age from pre-Cambrian (?) to Recent and consist of three general groups: 1) the old granitic gneissose and schistose rocks of the basement complex, associated felsic and mafic intrusives and meta-sedimentary rocks (Imataca formation); 2) an overlying younger series of sandstone, quartzite, shale, tuffs, and associated mafic intrusives (Roraima or Kaiturian, and Pastora series); and 3) Pleistocene and Recent terrace deposits, alluvium and deltaic sediments (Chart 1, column Z; figs. 2 and 18). The relations and age of pre-Pleistocene rocks are still only partly known, although Zuloaga (65) has grouped the rocks of the northern part of the State of Bolívar as follows:

Alluvium, deltaic, and llano beds of Tertiary and younger age;
Kaiteurian series, of Cretaceous age;
Pastora series, of Cretaceous (?) age;
Imataca series, of lower Paleozoic (?) age;
Archean complex, of pre-Cambrian age.

The Pastora and Kaiteurian may be subdivisions of the Roraima series [Liddle (23), p. 178], and recent work by Perfetti, and others (70) suggests that the Imataca formation may be part of the schist-gneiss-gneissic granite sequence of the so-called basement complex that was less effected by processes of migmatization or granitization than were the other pre-existing sedimentary rocks. They offer as corroborating evidence the structural parallelism of the Imataca series with the regional folds of the gneiss-granite-migmatite complex. Certainly at El Pao and along the road to Tumeremo, 18 kilometers east of Upata, the contact of the Imataca quartzite, and banding and bedding within it, appears to be conformable with the foliation of the underlying gneiss, and, as Zuloaga points out (65, p. 1185), some of the gneiss underlying rich iron ore at El Pao resembles ferruginous quartzite. Alternatively, as pointed out by Dengo and others (70) the observed data can be interpreted as the result of granitic invasion on a batholithic scale, followed or accompanied by regional metamorphism.

The basement complex in the northern part of the State of Bolívar consists in general of pale yellow or gray banded gneiss or gneissoid granite (migmatite of Perfetti), gneiss, mica schist, and intrusive (?) granite and basic igneous rocks (norite, diabase, gabbro), or, in the Gran Sabana region, of rhyolite and granitic porphyries [López, Mencher and Brineman (69), p. 858]. These rocks commonly contain quartz veins or masses and pegmatite dikes, and, in the northern part of the area, are closely associated with ferruginous quartzite (itabirite) of the Imataca series.

Structurally, the rocks of the basement are plicated on a large scale, with the trace of fault surfaces and axial planes trending dominantly northeastward (idem.). This major structure is clearly shown on aerial photographs, and work in progress by Perfetti, Dengo, Bellizia, and other geologists of the Dirección Técnica de Geología will undoubtedly contribute greatly to a better understanding of both structure and stratigraphy of these rocks.

These pre-Cambrian (?) rocks crop out in a few parts of the Gran Sabana, and extensively in a belt about 100 kilometers (60 miles) wide, parallel to the Orinoco, that extends from Territory Amazonas to the Atlantic Ocean. They were examined radiometrically at Ciudad Bolívar, and vicinity, along the road from Ciudad Bolivar to Guasipati, near Santa Elena (fig. 12), and at Santa Catalina (fig. 2).

The Pastora series crops out, and was examined radiometrically, from Guasipati to El Dorado and consists of green andesitic tuffs, agglomerate, and dolomitic shales [Zuloaga (65), pp. 1183, 1184]. The series may be in part correlative to the Carachapo member of Perfetti and Candiales (10) that was examined radiometrically in the vicinity of El Calcareo, and the series may be much older than was thought by Zuloaga (65). Part of it also probably is equivalent to the Cuyuni volcanic system of British Guiana according to Dengo and Bellizia (71).

The Roraima series, first described by Dalton [in Liddle (23), p. 175] from Mount Roraima is probably a pseudonym of the Kaiteurian series of British Guiana [Liddle (23), p. 178, López and others (69), pp. 867, 868].

The rocks included are basal conglomerates, sandstones, quartzites, jasper, and some tuff and shale injected by sills, dikes and laccoliths of quartz gabbro. The rock is generally white to gray-brown, but in part red, and reaches a maximum known thickness of at least 2,000 meters (6,500 feet) at Auyantepui (fig. 18) /Tate (64), p. 117, Liddle (23), p. 178/. It crops out extensively in the Gran Sabana where erosion has carved large mesas, cuestas, and table lands from the nearly horizontal beds. In southwestern Venezuela the Roraima rests directly upon eroded rocks of the basement complex, and in the northern areas of its exposure, upon the Pastora series. Its basal part was examined radiometrically at Santa Elena and Peraitepui.

Pleistocene and Recent sediments fill some stream channels, thinly veneer some areas of the basal complex, and form a thick delta at the mouth of the Orinoco river in Territory Delta Amacuro. They were examined at Rio Claro, El Calcareo, Santa Catalina, and Peraitepui. All of the rocks examined in the northern part of the State of Bolívar are more or less altered by weathering. In some places the rock is decomposed to a considerable depth, to a clay-quartz mixture, irregularly mottled with iron oxides, termed "tigrito." These weathered rocks or residual soils were examined along the road from Ciudad Bolívar to El Dorado.

The large rich iron, bauxite, alluvial, and quartz vein gold deposits, and the low-grade manganese deposits are of economic significance in the northern part of the area. In the Gran Sabana the gold and diamond placers have stimulated the imagination since the days of Sir Walter Raleigh.

Radiometric observations between Ciudad Bolívar and El Dorado, State of Bolívar

Radiometric observations were made at Ciudad Bolívar and vicinity (rio Candelaria; rio Claro, Cerro Toribio), and El Pao, El Muertico, El Calcareo, El Callao district, and El Dorado (fig. 18, no's. 1 to 6, inclusive). In addition, a continuous log of gamma radioactivity was made from Ciudad Bolívar to El Dorado, using for this purpose two Geiger-Mueller probes, each 40-inches (102 centimeters) long. These were mounted on the top of a Jeep and coupled to a Nuclear Instrument and Chemical Corporation Survey meter.

Ciudad Bolívar and vicinity

Rocks of the "basement complex" were examined radiometrically at Ciudad Bolívar (fig. 18, no. 1), at rio Candalaria (fig. 18, no. 1-A), at Cerro Toribio (fig. 18, no. 1-B), and rio Claro (fig. 18, no. 1-C) and vicinity. The latter three localities may be separate exposures of the same sequence of rocks repeated by folding in the Monte Cristo structure /Perfetti (70)/.

At Ciudad Bolívar.-- At Ciudad Bolívar (fig. 18, no. 1) gneissic granite (Migmatite of Perfetti), hornblende-feldspar gneiss (aluminous facies of Perfetti), and garnet hornblendite (garnetiferous facies of hornblendite of Perfetti) were examined at several places in the city. In rounded outcrops near the airport and in front of the church San Ysidro, highly feldspathic well-banded gneissic granite is composed of medium-grained shattered crystals of feldspars, quartz and biotite, accompanied by sparse, large crystals of magnetite, biotite, garnet, zircon, and samarskite(?) in pegmatitic veinlets. The radioactivity was 3 - 8; $\overline{5}$ (B), 2.5 - 4; 3 (G), but some sparse crystals of samarskite(?) as much as 2 centimeters square associated with similarly large crystals of magnetite, biotite, and garnet in fledspar pegmatitic veinlets were highly radioactive [11 - 16; $\overline{15}$ (B), 7-9; $\overline{8}$ (G)]. A chip sample of the gneissic granite, analyzed radiometrically in Caracas, contains 0.005 percent equivalent uranium. The radioactive samarskite(?) probably is as radioactive as similar material from rio Candelaria that contains 0.023 percent equivalent uranium. Neither the hornblende-feldspar gneiss, nor the garnetiferous hornblendite are appreciably radioactive; 1 - 3; $\overline{2}$, (G, B).

Along the rio Candelaria.-- Along the rio Candelaria, about 15 kilometers east of Ciudad Bolívar at a site known as Los Saltos, or Los Baños (fig. 18, no. 1-A), quartz-feldspar pegmatites have been injected along foliation planes of hornblende-biotite gneiss, that in turn is interlayered with feldspar-quartz granite gneiss, or migmatite of Perfetti and Candiales (10), the common country rock. Foliation strikes about N. 45° W. and dips nearly vertically. Narrow irregular apophyses of the pegmatite, especially in the hornblende gneiss, contain knots of biotite, some feldspar, and samarskite(?). The largest of the three such knots observed is about 1 foot (30 centimeters) square but tapers out irregularly. The radioactivity of the hornblende-biotite gneiss and of the feldspar-quartz granite gneiss is not appreciable (1 - 3; $\overline{2}$, B) but that of the samarskite (?) is 10 - 50; $\overline{20}$+ (B). A small specimen of the mineral, somewhat contaminated with biotite, contains 0.023 percent equivalent uranium. Similar abnormally radioactive clots of black minerals were also observed in similar host rocks about 1 kilometer downstream from Los Saltos. The radioactivity of the fine-grained clots was 4 - 7; $\overline{6}$, (B).

At Cerro Toribio.-- At Cerro Toribio (or Torivio), (fig. 18 no. 1-B), about 46 kilometers east of Ciudad Bolivar along the road to Upata, the carborne radiation meter deflected an abnormal amount (12 scale divisions versus a normal deflection of 3 divisions). Detailed observation indicates that most of the radioactivity is apparently caused by heavy minerals in sands and residual clays derived from granite gneiss containing pencil-thin pegmatitic facies, although some may be caused by radium or thorium absorbed in the clay. Cerro Toribio is a grass-covered hill composed of a sheeted quartz mass in the form of a dike about half a kilometer wide that extends for several kilometers N. 23° E. from the Cerro. Sheeting in the quartz strikes N. 15° to 40° W. and dips steeply southwest, the same attitude as the gneissic banding of foliation in the surrounding gneiss. In a half-mile traverse, the radioactivity of the quartz mass was found to be not appreciable (0 - 2.5; $\overline{2}$). The radioactivity of small patches of typical "tigrito" (residual soil) formed from the gneiss is as much as

5 - 7.5; $\overline{6}$ (B), although that of most of this material is 3 - 5; $\overline{4}$ (B). The radioactivity of sand derived from the gneiss and collected along the road gutters is from 3 - 5.5 and averages 4.5 scale divisions (B). A sample (T-1) of the most radioactive "tigrito" contains 0.004 percent equivalent uranium, and a sample (T-2) of the sand containing visible heavy minerals contains 0.005 percent equivalent uranium.

Rio Claro.-- Between 14 and 15 kilometers from Ciudad Bolívar, a road that leads 37.3 kilometers southwest to the rio Claro (fig. 18, no. 1-C), crosses diagonally the strike of a series of banded gneiss (migmatite), equigranular hornblende-quartz-feldspar rock, and gneissic granite-porphyry(?), containing narrow pegmatitic injections, or porphyritic facies of similar rock that are as much as 1 foot (30 cm) in width. The banded gneiss with accompanying coarsely crystalline facies resembles the rock at Cerro Toribio and that at Candelaria. They may be the same group of rocks repeated by folding, although the hornblende-gneiss at Rio Candelaria was not seen in the other localities. The radioactivity of the banded gneiss (migmatite) was 3 - 7; $\overline{5}$ (B), that of granite porphyry(?) 2 - 5; $\overline{3.5}$ (B), and that of "tigrito" derived from gneiss, 3 - 5; $\overline{4}$ (B). Recent sand containing an appreciable proportion of heavy minerals, including monazite, is concentrated along the banks of some of the smaller streams and the rio Claro. The radioactivity of this materials was an average of 17 scale divisions (beta-gamma), $\overline{13}$ (gamma) at a small stream north of rio Claro; and $\overline{17}$ (B), $\overline{11}$ (gamma) at the rio Claro. Samples were taken of radioactive sand and "tigrito" (no. E), of radioactive sand at the small stream north of rio Claro (no. F), and of sand with visible monazite at rio Claro (no. G) for further radiometric analysis in Caracas. The samples contain respectively 0.019, 0.06, and 0.087 percent equivalent uranium. Heavy-mineral separations were made of samples no. F and no. G and examined under the microscope. They both contain abundant magnetite and zircon and sparse monazite, although monazite and zircon were more abundant in sample no. G than in sample no. F, and in sample no. G trace amounts of garnet were observed. Zircon is in opaque prisms or colorless grains. The magnetite, colorless zircon, and monazite are all well rounded, suggesting that they were transported farther before deposition than the prismatic zircon.

El Pao

El Pao (fig. 18, no. 2), about 143 kilometers east of Ciudad Bolívar, is the site of the operating iron mine leased by Iron Mines Company of Venezuela (Bethlehem Steel Company), San Féliz.

The rocks of El Pao comprise from youngest to oldest, Canga, intrusive norite, ferruginous quartzite (itabirite), hematite ore, ferruginous clay, and banded gneiss (migmatite) or granite(?). The Canga is a breccia of quartzite fragments more- or less-cemented by hematite, limonite, clay, and bauxite that is derived from the ferruginous quartzite. The norite is a dark gray-green equigranular medium-grained massive intrusive rock. Blue-black hard hematite ore, containing as much as 70 percent Fe (within a fraction of 1 percent pure hematite) overlies softer less-ferruginous sandstone and gneiss or granite(?), and terminates downward abruptly against highly argillized gneiss or granite(?). The ferruginous quartzite (itabirite) of the Imataca series, where observed, is friable but elsewhere in the deposit is reported by Zuloaga (65), and Wright and Wheaton (72) to be more typical quartzite. The rock is medium-grained, equigranular, composed of subangular to subrounded quartz grains, and interlaminated with magnetite and hematite. Zuloaga and Tello B, state (66, pp. 12, 25) that it contains an average of about 45 percent iron and that hematite is a late alteration product of original sedimentary magnetite. Where observed in road cuts excavated for open pit mining, and also at Gutierrez Hill, the attitude of relict banding in the rich iron ore and of the contact of the underlying gneiss or granite(?) itself is exactly concordant with that of the foliation of the underlying granite(?), or gneiss although Zuloaga reports (65) the contact is elsewhere obscured by intrusive granite. The sharpness of the contact between "lean ore" (hematitic, argillized gneiss) and argillized gneiss in the road cut above the mill suggests that alteration banding was affected, or was guided by original foliation or bedding, but the contact of rich quartzitic hematite at Gutierrez Hill is probably the true contact of the Imataca formation and underlying gneiss or granite. In form the deposit is a bowl or synclinal basin, intruded by norite.

The radioactivity of all the rocks observed was slight, although that of the altered gneiss or granite was 1 - 3; $\overline{2}$ (B). The rich hematite ore was nonradioactive; one observation beneath an overhang of the ore was 0 - 0; $\overline{0}$ (B).

El Muertico

As it appeared to be representative of the residual manganese deposits of the northern part of the State of Bolívar, we examined the concession known as El Muertico on the Cerro Santa Rosa about 10 kilometers south of Upata (fig. 18, no. 3).

In a pit 8 feet deep, ferruginous quartzite (itabirite) is overlain by a breccia of limonite-cemented itabirite that grades upward into residual manganiferous, limonitic sandy clay. The radioactivity of these materials ranged from 0.5 to 2 scale divisions; averaging 1 (B), and is, therefore, not appreciable.

El Calcareo and vicinity

Along the Upata-Tumeremo highway about 25 kilometers east of Upata an intersecting road leads to El Palmar to the east and to the Carachapo River and El Calcareo about 20 kilometers to the southwest (fig. 18, no. 4).

El Calcareo, at the base of the Sierra Tomasote, is on a flat terrace covered with granite gneiss, that is in part residual, and in part detrital. Cement consists of white caliche (sodium and calcium carbonates). The radioactivity of the material is not appreciable; 1 - 2; $\overline{1.5}$ (B).

At the Carachapo River the Carachapo member (probably the Pastora series of Zuloaga) is exposed along the stream banks. The rock is a green hornblende-chlorite schist that was not detectably radioactive; 0 - 1.5; $\overline{0.5}$ (B).

El Callao district

The gold mining district of El Callao (fig. 18, no. 5) was discovered in 1853, and according to Miller and Singewald (37) by 1857 had produced 1,438,638 ounces of gold from placers and veins and was the richest district in the world. Production from 1871 to 1890 is recorded as more than $30,000,000 /Newhouse and Zuloaga, (73)/. The general geology of the district is illustrated in figure 19. Gold-quartz veins of general east to northeast strike and south to southeast dip have been injected in gently folded green andesites and diabase of the Pastora series, and gabbro. The veins in general strike parallel to the axial traces of the folds, and consist of multiple injections of quartz in convoluted structures forming a small lode system for each vein. Free gold is commonly associated with sparse pyrite and selvages of andesite along the sides of the veins. The radioactivity of all of the rock types exposed and examined in the Callao district was not appreciable, ranging from 0 to 2 scale divisions and averaging 0.75 divisions (B). Rocks examined include andesite, aplite, augite-biotite porphyry dike rock, jasper, and quartz in the Laguna and El Perú mines (fig. 19, A and B), quartz at the Mamón vein and alluvium at Hansa flat (fig. 19, C); and andesite, pillow lava, and gabbroic(?) country rock elsewhere in the district (fig. 19, D). In addition, four screened placer samples from Quebrada Mocupia, near Nacupay (fig. 19) were furnished by R. P. Morrison, Dirección de Minas. These samples, examined radiometrically in the Caracas laboratory, contain less than 0.001 percent equivalent uranium.

El Dorado

El Dorado (fig. 18, no. 6) is about 400 kilometers (240 miles) by road southeast of Ciudad Bolívar at the junction of the Yuruari and Cuyuní Rivers. Gold has been mined from placer deposits of the area and from some of the quartz veins that transect mafic igneous rocks. In the yard of the penal colony a glassy quartz vein about 6 feet (1.8 meters) wide contains a few vugs and a few crystals of magnetite. The vein trends N. 60° E. dips 60° southeast and was injected into green andesite and quartz-porphyry intruded by diabase. The radioactivity of residual soil derived from the mafic rocks, the mafic rocks, the quartz vein, and sand from the banks of the Cuyuní river was not appreciable; 0 - 2; I, (B).

Radiometric observations in the Gran Sabana, State of Bolívar

The Gran Sabana in the southeastern corner of Venezuela (fig. 2) occupies approximately the southern third of the State of Bolívar and consists topographically of broad upland valleys and peneplains surmounted by isolated scarped table lands (Tepuys). The altitude of the Sabana ranges from 810 meters (2,624 feet) to 2,630 meters (8,628 feet) /Tate, (64)/ at Mount Roraima. This magnificently scenic region is covered largely by grass where the soil is derived from the Roraima formation, or by dense jungle where the soil is derived from mafic igneous rocks.

Radiometric observations were made at Santa Elena and vicinity (fig. 18, no. 7), and at Peraitepuy (fig. 18, no. 8).

Santa Elena and vicinity

Santa Elena, at the southeastern edge of the Gran Sabana (fig. 18, no. 7) is situated on alluvial outwash derived from the basal Roraima formation and from older volcanic rocks. Quartz porphyry of the old basal complex extends from 3 kilometers south of the town, southward into Brazil; from 1 to 2 kilometers south of Santa Elena a thick gabbro sill has been injected into the Roraima formation near its base. The reconnaissance of Aguerrevere, López, Delgado and Freeman (67) shown on figures 2 and 18, and later studies by López, Mencher, and Brineman (69), describe the geology.

The basal beds of the Roraima were examined on a 5 kilometer traverse west and north of Santa Elena; they consist of well-bedded pale cream micaceous sandstone and conglomerate, some maroon sandy siltstone, and some orange jasperoid. The well-rounded pebbles in the conglomerate consist predominantly of shattered quartz, although some quartz porphyry and ferruginous laminated quartzite was noted. Pebbles are as much as 10 centimeters in diameter and are in a clay-sand matrix. Beds are commonly from 30 centimeters to 1 meter thick, and are in general evenly bedded, although some cross-bedding was seen.

The gabbro sill is a medium-grained dark green rock that in general supports dense jungle. The rock is massive where exposed east of Santa Elena in the hill known as El Calvario. Thin sections of this rock examined in Caracas show it to be a hypersthene dunite containing pigeonite and diallage with diabasic (ophitic) texture.

The basal complex, examined in a traverse of about 11 kilometers south of Santa Elena to San Domingo, consists of a green quartz-sanidine(?) porphyry that weathers gray-brown. North of Santa Elena this rock is deeply lateritized.

Radiometric observations made of all these rocks and of alluvium derived from them disclosed no appreciable radioactivity; the instrument pointer fluctuated between 0 and 3 scale divisions and averaged about 1.5, (B).

Peraitepuy

Peraitepuy, about 30 kilometers west of Santa Elena may be reached from Santa Elena in a 10-minute flight or by a 2-day walk. The airport is on top of a mesa of Roraima sandstone and is about 6 kilometers west of the operating open-pit diamond workings, called La Joyada, of the Compañia Venezolana de Diamante.

La Joyada.-- The company, using a clam-shell bucket, trucks, and a small gravity mill capable of handling 150 cubic meters daily, produces, in each 16 hours, from 5 to 50 karats of diamonds and a small amount of gold according to Castro (74). The diamonds are commonly coated with some substance that gives them a green color, and inasmuch as the green color of some diamonds is thought by Davidson and Bowie (75) to be caused by radioactivity, the diamonds of Peraitepuy were of particular interest. The diamonds, associated with zircon, tourmaline, jasper, magnetite and limonite pellets, occur in a zone (the formación) from a few centimeters to 1 meter thick, of white clay-gravel composed predominantly of quartz pebbles. The diamond-bearing "formación" rests on mottled white and buff clay (the Cascajo), and is overlain by black soil (the Cogote) and quartz-pebble gravel cemented by calcium carbonate (the Caliche). The deposit worked is in an old stream valley that is very close to the base of the Roraima formation; Aguerrevere and others (67, p. 330) thought the diamonds are weathered from these basal beds.

The radioactivity of the diamonds and the enclosing soil and stream deposits was not appreciable; 1 - 3; $\overline{2}$, (B). The heavy minerals (indicaciones) left after being cleaned of gold and diamonds were spread on the ground near the mill; this residue was also not detectably radioactive.

La Faisca.-- The abandoned placer gold and diamond camp of La Faisca, about 10 kilometers by Jeep east of the airport, is along a stream-valley that drains the basal conglomeratic beds of the Roraima formation. Subrounded quartz boulders as much as 45 centimeters in diameter are abundant, and some large euhedral quartz crystals were seen. A traverse from La Faisca was made stratigraphically up through the deeply weathered greenish porphyritic rock into conglomeratic sandstone of the Roraima formation that contains some vein-quartz sills; the maximum radioactivity observed was 3 scale divisions (B), and the average about 2 (B), and the rocks are, therefore, not appreciably radioactive.

Zone of black sand in Roraima sandstone.-- A zone of black sand in Roraima sandstone is exposed in the road cut about 20 feet beneath the top of the first broad bench formed by Roraima sandstone above La Joyada. The zone is about 4 meters thick and consists largely of friable white to pink cross-bedded sandstone. The crossbeds, here, as well as in sandstones exposed on top of the mesa of Peraitepuy south of the airport, indicate that the streams probably flowed from the southeast to the northwest. The sandstone is composed predominantly of subangular quartz grains stained by hematite; within the sandstone are conspicuous thin bands, from a few millimeters to a centimeter thick, of black minerals.

The radioactivity of the beds above and below the black sand zone is not detectable; 1 - 2.5; $\overline{2}$ (B), but that of the zone of the black sand beds is detectable, although variable. The radioactivity of the most highly radioactive bed, 1 centimeter thick, was 5 - 6; $\overline{5.5}$ (B). Samples of this contain 0.01 percent equivalent uranium, and a heavy-mineral separation of this sample examined under the microscope contains abundant magnetite and hematite, less abundant zircon, and sparse monazite. This black sand bed is not of economic interest but more radioactive sands may be found in the Roraima series.

Icabarú

Although no radiometric observations were made in the vicinity of Icabarú (fig. 18, no. 9), the opportunity was taken to talk with George Kirkbride, diamond buyer. He had collected some of the heavy minerals associated with diamonds and gold (indicaciones) and sent them to his diamond cutting shop in Florida. A sample of this material analyzed by the United States Geological Survey Trace Elements Section, Washington Laboratory, contains only 0.003 percent equivalent uranium, but may not be representative of indicaciones from the entire region.

Radiometric observations near Santa Catalina, Territory Delta Amacuro

Santa Catalina is a small village on the south bank of the Caño Piacoa which is a short branch of the Rio Grande, the southernmost tributary of the Orinoco River (fig. 2). The village was reached by launch in six hours from Tucupita which is 3-1/2 hours, by launch east of Barrancas, the easternmost airport for regular commercial flights.

In the Quebrada Adán, about 5 kilometers southeast of Santa Catalina, Dr. Ricardo Falero, Juan Figuera, and Ismail Gouland have a gold and zircon concession. The concession covers an old alluvial deposit and has been tested by a series of pits over an area about 120 meters long and 30 wide. A representative section from top to bottom exposed in one of the pits is: 15 centimeters of dark brown to buff clay soil with some sand, 61 centimeters of buff clayey sand and sandy clay; and 45 centimeters of gray clayey sand. The radioactivity of these three zones is, from top to base, 0 - 1; 0.5 (B); 1 - 3; 2 (B); and 2 - 3.5; 2.5 (B). Zircon in subangular prismatic brown crystals that are as much as 1 centimeter in length is concentrated from the sand. Samples taken at 6-inch intervals down the pit wall and of batea (analagous to "gold-pan") concentrates from one pit were unfortunately misplaced. A sample of cleaned zircon concentrate furnished by Dr. Falero and analyzed in Caracas, however, contains 0.73 percent equivalent uranium. Under the microscope the concentrate is seen to be composed predominantly of rounded grains of magnetite, although subangular quartz and feldspar grains are abundant. About 30 percent of the sand is composed of small rounded colorless grains and large euhedral purplish-brown crystals of zircon. Slightly rounded light pink fragments of garnet, sphene, and amphibole are less abundant. Dr. Falero states that trace amounts of gold and diamonds have also been found.

The gravels have apparently been derived from granitic and gneissic rocks of the region [López, and others, (68)] and the occurrence of these radioactive heavy minerals here and near Ciudad Bolívar suggests that radioactive minerals are widespread in some of the gneissic rocks in the northern part of the Brazilian shield. The deposit itself probably does not merit more field work, but if petrographic study and chemical analyses show an appreciable amount of other rare elements, more study of this and surrounding areas should be undertaken.

Road log of gamma-ray activity

A record of gamma-ray activity was kept from Ciudad Bolívar to El Dorado using the carmounted Geiger-Mueller probes previously described. The equipment used has a normal counting rate of about 1,500 counts per minute as compared to the 30-60 counts per minute normally recorded by the small hand-portable rate meters and has been successfully used in the United States of America for both reconnaissance and detailed prospecting, as well as for tracing known radioactive rocks within small areas of low relief and altitude. The instrument used easily detected "tigrito" and radioactive sand near Cerro Toribio, samples of which contain only 0.004 percent equivalent uranium.

The general results of the road traverse from Ciudad Bolívar to El Dorado indicate that sands containing heavy minerals derived from some of the banded gneiss containing narrow pegmatitic facies are the most radioactive, followed in order of decreasing radioactivity by granite(?), residual soil, laterite, itabirite, hematite ore, norite, gabbro, diabase and andesite, and hornblende-chlorite schist. In terms of formations, the order of decreasing radioactivity is 1), gneiss of the basement complex, 2), residual soil and laterite, 3), Imataca formation, 4), Pastora series, and 5), the Carachapo member.

The background level of radiation was 2.5 scale divisions or 1,500 counts per minute (the 2 milliroentgen per hour sensitivity position was used throughout the trip) on paved roads in Ciudad Bolívar, and about 1.8 scale divisions on a launch in the middle of Caroní river. The basic rocks of the Pastora series and the Carachapo member, the norite near El Pao, the rich hematite ore of El Pao, and the mafic rocks within the basement complex deflected the meter only slightly above background, that is, from 1 to 3 scale divisions. The instrument generally fluctuated between 3 and 8 scale divisions upon the more felsic rocks of the basement, although at Cerro Toribio and at kilometer 52 on the road from Ciudad Bolívar to Upata the reading was 12.5 scale divisions. The maximum deflection reached was 17 scale divisions at rio Claro (Fig. 18, no. 1-C), and a sample of the radioactive sand from there contains 0.087 percent equivalent uranium.

Data are inadequate to calibrate the instrument deflections on the carborne equipment in terms of deflections on the smaller hand portable equipment, but data obtained suggest the following correlation:

Carborne meter deflection	Hand-portable meter deflection
17	12
15	10
12	7
10	6
5	3

Various attempts have been made by the United States Geological Survey to calibrate meter reading of either hand portable or carborne radiation meters in terms of percent equivalent uranium, but except in areas of exceptionally uniform terrain where minute radioactive minerals are uniformly distributed the attempts have been successful only in general terms.

In future work in the northern part of the State of Bolívar the carborne radiation equipment should prove of great utility, but the data obtained should be cross-checked by means of radiometrically analyzed samples.

Summary and conclusions

During the reconnaissance for uranium in the State of Bolívar and Territory Delta Amacuro, radiometric observations were made of all principal rock types exposed in their principal areas of exposure, that is, the rocks of the Archean(?) basement complex in the northern part of the area and in the extreme southwestern corner of the Gran Sabana, the Imataca and Pastora series between El Pao and El Dorado, the Roraima (or Kaiteurian) series in the Gran Sabana, and alluvial deposits in all areas covered. The use of the carborne Geiger counter in the road traversed between Ciudad Bolívar and El Dorado gives some assurance that the route traveled was fairly well prospected, but much more work will be required before the uranium potentialities of the vast area south of the Orinoco will be clearly known.

The results of this radiometric reconnaissance suggest that some of the more felsic rocks of the basement complex and of the basal Roraima series are worth additional study but that the more mafic rocks of the Carachapo member, of the basement complex, of the Pastora series, and of the Roraima series are apparently devoid of radioactivity and probably do not warrant additional study. The deposits of bauxite, hematite, manganese oxides, and the gold-quartz veins are also not appreciably radioactive, although additional study is merited of some other gold-quartz vein deposits, especially those that contain an appreciable quantity of base-metal sulfides. It can be expected that some of the heavy minerals concentrated with gold and diamonds in the placer deposits of the area will be radioactive, although those examined are not appreciably so. It would be of interest to determine the constituents of the green material coating the diamonds from the Gran Sabana, and in further study of such deposits in the region, thucholite [Davidson and Bowie, (75)] should be searched for.

The basal sandstones and conglomerates of the Roraima series, where examined, are not appreciably radioactive with the exception of the zone of radioactive black sand at Peraitepuy. Nevertheless, the fact that zircon occurs at Peraitepuy suggest that zones containing richer deposits of zircon and perhaps other radioactive minerals might be found by additional study; moreover the numerous sills of vein quartz suggests that igneous intrusive rocks, possibly associated with the quartz-porphyry sills, underlie the area. Therefore, even though no indications of metallic mineralization of the "red beds" type have been reported, the presence of intrusive igneous rock, of detrital uranium minerals and of highly porous and probably permeable beds of the basal Roraima make these beds potential host rocks for deposits of the "red beds" type. We, therefore, suggest a continued search for carnotite or copper-uranium deposits in the basal Roraima series.

Some of the residual clays derived from the rocks of the basement complex contain as much as 0.004 percent equivalent uranium. This material probably contains only trace amounts of uranium, but chemical analyses are required to substantiate the supposition.

The pegmatitic facies of banded granite gneiss (migmatites) of the basal complex and heavy mineral placer concentrations derived from this rock appear to offer the most promise of immediate reward for future work. Samples of sands contain from 0.019 to 0.73 percent equivalent uranium, and, even though most of the radioactivity of the contained monazite, zircon, samarskite, and other minerals may prove on chemical analyses to be caused by thorium, further study of areas along the northern border of the Brazilian shield may disclose deposits richer in these minerals that may be of commercial value. The fact that specimen quantities of rare earth-uranium-thorium minerals such as samarskite(?) have been found in place suggests that further search will disclose more such deposits, but unless exceptionally rich or numerous they will probably not be of great economic interest. The probability that these abnormally radioactive rocks are in relatively thin zones that can be traced radiometrically at the outcrop, or by radioactive residual soil and placer deposits derived from them, may prove to be of practical use in field mapping. In the mapping, it would be desirable to compile an isoradioactivity map of the area studied, from data obtained by using the carmounted radiation detectors.

PRELIMINARY SURVEY OF GAMMA-RAY WELL LOGS

Summary

Gamma-ray well logs were examined for significant radioactivity from more than 140 representative wells in most of the oil fields of Venezuela. The logs were rectified to a standard sensitivity scale of 10 inches and were approximately calibrated to read in percent approximate equivalent uranium for better comparison with rock samples.

Gamma-ray logs are described from all the oil field areas and the abnormal gamma-ray deflections on the logs are evaluated. The most radioactive rocks found and discussed in relation to the geology are the black calcareous, phosphatic basal shale beds of La Luna formation of Cretaceous age in the western Maracaibo basin. These basal beds, called the "fish-bone" beds, probably contain about 0.014 percent approximate equivalent uranium 1/ in some thin beds. The radioactivity recorded from wells in eastern and central Venezuela is less prominent and the slightly radioactive rocks are erratically distributed. The greatest radioactivity in eastern and central Venezuela, about 0.006 percent approximate equivalent uranium, is probably caused by carbonaceous and lignitic beds in the Oficina formation of Oligocene age.

Recommendations are made for the continuance of the study of gamma-ray logs as one simple means of amassing data on the radioactivity of rocks and fluids and as a guide to areas and rocks of interest in the program of uranium investigations in Venezuela.

Introduction

A preliminary survey of gamma-ray logs was made during June and July 1951 to accumulate additional data about the radioactivity of rocks in Venezuela. Gamma-ray logs representative of the different drilled areas were obtained from most of the oil-producing companies. The following discussion is a resume of this study and includes data from all the major oil fields and a number of the smaller ones.

Gamma-ray logs show the gamma radioactivity of the materials in the well logged and are commonly used in such studies as stratigraphic correlation, determining porosity and liquid saturation; they are also used to record casing depths. The data obtained may be used to indicate rocks or areas of abnormal radioactivity requiring field study, as well as to delimit rocks or areas of little radioactivity requiring no study. The study of the logs will contribute to a better understanding of the distribution of uranium in sedimentary rocks. In addition, if sufficient data

1/ A term used to denote the amount of radioactivity calculated from gamma-ray logs.

are available, the logs may be calibrated semiquantitatively and used in the calculation of low grade reserves of uranium ore.

Until recently the gamma-ray logs made in Venezuela were usually without a zero reference line from which the amplitude of deflections could be measured directly. Many of the logs examined were without this zero reference and the amplitude of deflections in these logs was estimated by comparison with logs containing zero references in adjacent wells.

Instruments for gamma-ray logging are usually adjusted in sensitivity to record best the radioactivity of the material logged. The so-termed sensitivity scale is analagous to the range or sensitivity position of the portable ratemeters and refers to the maximum distance that the recording pen could travel on the log paper. In traversing material of different radioactivity, the sensitivity scale could be as much as 20 inches to expand the record of subnormal radioactivity, or as little as 4 inches to compress the record of abnormal radioactivity. Most materials in Venezuela are recorded on a sensitivity scale of between 7.5 and 10 inches. In order to compare the radioactivity shown on gamma-ray logs with that of samples, a conversion factor is required. Gott and Hill (47) have found by the application of radiometric analyses of many core samples that each inch deflection on a 10-inch sensitivity scale represents approximately 0.0007 percent equivalent uranium. The conversion factor is only approximate, and in our preliminary study was applied without regard to casing, fluid content of well, or other factors that might alter the conversion number. For example, in the case of large sharp anomalies the factor would tend to be low because of the response-time lag of the electronic apparatus. The figures of approximate equivalent uranium that were calculated from the gamma-ray logs are, therefore, by no means exact but are in the same general units reported in normal radiometric analysis and therefore afford a base of comparison; the conversion factor approximately checks the radiometric analyses of core samples taken in the western part of the State of Zulia.

Personal visits to examine gamma-ray logs were made to the Socony-Vacuum Oil Company of Venezuela; the Mene Grande Oil Company, C. A.; the Texas Petroleum Company; the Creole Petroleum Corporation; and the Shell Caribbean Petroleum Company. Gamma-ray logs were also obtained from the Pantepec Oil Company; the Sinclair Oil and Refining Company; Phillips Oil Company; S.A.P.L.M. (S.A.Petrolera Las Mercedes); the Venezuelan Atlantic Refining Company; and the Richmond Exploration Company. Mr. Keith Miner and Mr. Jay Beaver of the Petrotec Company freely gave advice on calibration technicalities and much information on logs of interest.

Among the principal references to the geology of the oil fields of Venezuela, those consulted during this investigation are the papers of Hedberg, Sass, and Funkhauser (76) and (77), Staff of the Shell Caribbean Petroleum Company (46), and Mencher, and others (50).

Gamma-ray well logs examined

The location of the oil fields of Venezuela and of the wells whose gamma-ray logs were examined are shown on figure 20, and a list of the wells whose logs were examined is given in table 7. These wells are grouped by areas, within each of which the general structure and the stratigraphy are about the same. These areas, discussed in order from eastern to western Venezuela are: the Jusepín-Santa Bárbara area, the San Joaquín-Guárico area, the greater Oficina area, north-central Venezuela, eastern Falcón, the Bolívar Coastal Fields, northwest Zulia, and the Barinas area. The stratigraphic sections of these areas are shown on Chart 1, columns A through Z, and the general geology, on figure 2.

Jusepín-Santa Bárbara Area

The Jusepín-Santa Bárbara area is in the northwestern part of the State of Monagas within the Maturín basin. Eight gamma-ray logs were examined in the Quiriquire, Jusepín, and Mulata fields (fig. 20). In general the wells in this area penetrate rocks of Miocene to Eocene age which are the oil-producing formations [Mencher and others. (50)]. The stratigraphic section is shown on chart 1, columns V and T.

The Quiriquire field

In the Quiriquire field, well Q-290 extends through the Nuevo Mundo (Tinajitos) formation of the Merecure group, both of upper Eocene and Oligocene age. Unconformably above the Nuevo Mundo is the Los Jabillos formation of Oligocene age. A slight increase in gamma-ray activity was logged at the unconformity between the two sandstone units. Two other small gamma-ray peaks in the well log were reflected from a dark glauconitic, oily sandstone, and a glauconitic shale in the upper part of the Nuevo Mundo. The peaks represent about 0.003 percent, or less, approximate equivalent uranium.

The Jusepín field

In the Jusepín field, the deepest penetration was to the Carapito shale of Oligocene age. In well J-125 only a small gamma-ray peak is shown near the top of the Carapito shale, otherwise the radioactivity of the formation is low and regular. The La Pica formation is slightly more radioactive than the underlying Carapito shale.

Table 7.- Wells of Venezuela whose gamma-ray logs were examined

Field	Well	District	State	Company 1/
		Jusepín-Santa Bárbara area		
Quiriquire	Q-290	Bolívar	Monagas	Cr.
Jusepín	J-125	Maturín	do.	Cr.
Do.	J-134	do.	do.	Cr.
Do.	J-137	do.	do.	Cr.
Mulata	MP-136	do.	do.	Pan.
Do.	MP-147	do.	do.	Pan.
Do.	MP-42	do.	do.	Cr.
Santa Bárbara	SB-133	do.	do.	Sin.
		San Joaquín-Guario Trend		
Exploration	La Vieja-3	Freites	Anzoátegui	M.G.
Santa Rosa	RG-14	do.	do.	M.G.
El Roble	RPN-22	do.	do.	Pan.
Do.	RPN-23	Aragua	do.	Pan.
Do.	RPN-24	Freites	do.	Pan.
Do.	RPN-25	Aragua	do.	Pan.
Do.	RPN-26	Aragua	do.	Pan.
San Roque	La Loma-2	do.	do.	Ph.
Do.	B-20	do.	do.	Ph.
Do.	B-22	do.	do.	Ph.
Rincón Largo	Araque-3	do.	do.	Ph.
Do.	Araque-6	do.	do.	Ph.
Do.	Rincon-1	do.	do.	Tex.
Santa Ana	AM-9	do.	do.	M.G.

1/ The abbreviations of the Companies are as follows: Cr.--Creole Pertroleum Corp.; Pan.--Pantepec Oil Co.; Sin.--Sinclair Oil and Refining Co.; M.G.--Mene Grande Oil Co.; Ph.--Phillips Oil Co.; Tex.--Texas Petroleum Co.; S.V.--Socony Vacuum Oil Co. of Venezuela; L.M.--S. A. Petrolera Las Mercedes; V.A.--Venezuela Atlantic Refining Co.; Shl.--Shell Caribbean Petroleum Co.; Rich.--Richmond Exploration Co.

Table 7.--Wells of Venezuela whose gamma-ray logs were examined--Continued

Field	Well	District	State	Company
Santa Ana	AM-10	Aragua	Anzoátegui	M.G.
Toco	TM-9	Freites	do.	M.G.
Do.	TM-10	do.	do.	M.G.
Guere	Guere-1	do.	do.	Sin.
Do.	Guere-2	do.	do.	Sin.
Do.	Guere-4	do.	do.	Sin.
Soto	SV-3	do.	do.	S.V.
Mapire	SG-13	do.	do.	M.G.
The Greater Oficina Area				
Caico Seco	CaZ-4	Aragua	Anzoátegui	M.G.
Boca	SG-102	Freites	do.	M.G.
Chimire	CVH-44R	do.	do.	S.V.
Do.	CVH-59R	do.	do.	S.V.
Do.	CVH-60R	do.	do.	S.V.
Do.	CVH-64R	do.	do.	S.V.
Do.	CVH-62	do.	do.	S.V.
Do.	NS-310	do.	do.	M.G.
Do.	OM-328	do.	do.	M.G.
Nipa, West	NV-7	do.	do.	S.V.
Do.	NV-8	do.	do.	S.V.
Do.	NV-9	do.	do.	S.V.
Do.	NV-11	do.	do.	S.V.
Do.	NV-18	do.	do.	S.V.
Do.	NV-23	do.	do.	S.V.
Do.	WNZ-47	do.	do.	M.G.
Do.	Mata-1	do.	do.	Tex.
Do.	Mata-2	do.	do.	Tex.
Nipa, East	ENZ-121	do.	do.	M.G.
Do.	NZ-203	do.	do.	M.G.
Do.	NZ-213	do.	do.	M.G.
Guico	GV-21	do.	do.	S.V.
Do.	GV-26	do.	do.	S.V.
Do.	GV-28	do.	do.	S.V.
Do.	GV-67	do.	do.	S.V.
Do.	GV-68	do.	do.	S.V.
Oficina	OG-300	do.	do.	M.G.
Do.	OG-151	do.	do.	M.G.
Dación	EGS-114	do.	do.	M.G.

Table 7.--Wells of Venezuela whose gamma-ray logs were examined--Continued

Field	Well	District	State	Company
Leona	LG-30	Freites	Anzoátegui	M.G.
Do.	LG-102	do.	do.	M.G.
Do.	LG-207	do.	do.	M.G.
Areo	Areo-1	do.	do.	M.G.
		North Central Venezuela		
Las Mercedes	M-5, M-8, M-10 M-45, M-85	Infante	Guárico	L.M.
	M-131))27 wells	do.	do.	L.M.
	M-232)	do.	do.	L.M.
Lechosa	Lechosa-2	do.	do.	Tex.
Tucupido	Monal-3	do.	do.	V.A.
Do.	MGX-6	Zaraza	do.	V.A.
Do.	SaGX-1	do.	do.	V.A.
Sabán	Sabán-2	do.	do.	Ph.
Ruiz	Ruiz-3-7	Infante	do.	V.A.
Do.	Ruiz-3-57	do.	do.	V.A.
		Eastern Part of the State of Falcón		
Cumarebo	Cu-117		Falcón	Cr.
		Bolívar Coastal Fields		
Mene Grande	MG-415	Baralt	Zulia	Shl.
Do.	MG-616	do.	do.	Shl.
Do.	MG-626	do.	do.	Shl.
Bachaquero	LB-684	Bolívar	do.	Shl.
Do.	LB-686	do.	do.	Shl.
Do.	LB-692	do.	do.	Shl.
Do.	LB-694	do.	do.	Shl.
Do.	LB-696	do.	do.	Shl.
Do.	LB-700	do.	do.	Shl.
Do.	LB-745	do.	do.	Shl.
Do.	Lagunilla-19	do.	do.	M.G.

Table 7.--Wells of Venezuela whose gamma-ray logs were examined--Continued

Field	Well	District	State	Company
Lagunillas	LS-1370	Bolívar	Zulia	Shl.
Do.	LL-428	do.	do.	Cr.
Do.	LL-434	do.	do.	Cr.
Do.	LL-446	do.	do.	Cr.
Do.	LL-447	do.	do.	Cr.
Tía Juana	TJ-223	do.	do.	Cr.
Do.	TJ-225	do.	do.	Cr.
Do.	TJ-226	do.	do.	Cr.
Do.	TJ-229	do.	do.	Cr.

Northwestern Part of the State of Zulia

Field	Well	District	State	Company
Mara	Rabán-3	Mara	Zulia	Tex.
Do.	Rabán-4	do.	do.	Tex.
Do.	Rabán-10	do.	do.	Tex.
Do.	Rabán-12	do.	do.	Tex.
Do.	Rabán-14	do.	do.	Tex.
Do.	Rama-1	do.	do.	Tex.
Do.	Dm-23	do.	do.	Shl.
Do.	MA-2	do.	do.	Cr.
Do.	MA-9	do.	do.	Cr.
La Paz	P-101	Maracaibo	do.	Shl.
Do.	P-114	do.	do.	Shl.
Rio del Sarro	Z-15-1	Perijá	do.	Rich.
Macoa	Z-20-1	do.	do.	Rich.
Do.	Z-25-1	do.	do.	Rich.
Alturitas	Alturitas-1	do.	do.	Cr.

The Barinas Area

Field	Well	District	State	Company
Barinas	Silvan-2	Barinas	Barinas	S.V.
Do.	Silvan-6	do.	do.	S.V.
Do.	Silvan-3	do.	do.	S.V.

The Mulata field

At the Mulata field, farther south, in well MP-42, a slight gamma-ray peak was observed at the contact of La Pica and Las Piedras formation of upper Miocene age.

In all fields in the Jusepín-Santa Bárbara area no abnormal gamma-ray activity was observed, although the gamma-ray logs lacked zero reference points as well as sensitivity settings. All the small gamma-ray peaks are estimated to correspond to about 0.003 percent approximate equivalent uranium and probably represent the shaley zones or thin carboniferous glauconitic beds in the rocks.

San Joaquín-Guario area

Southwest of Santa Bárbara in the State of Anzoátegui and in line with the same structural trend, is the San Joaquín-Guario area, sometimes referred to as the San Joaquín-Guario Trend [Hedberg and others, (77)]. This area includes a group of 10 or more fields, some of which are the El Roble, Santa Rosa, Santa Ana, San Roque, Rincón Largo, Toco, Guere, Soto, Mapire, and La Vieja fields. In all fields, 22 gamma-ray logs were examined.

The rocks penetrated in these fields are, in general, those penetrated in the Jusepín-Santa Bárbara area according to Mencher and others (50) and Hedberg and others (77), and comprise the Oficina and Freites formations of the Santa Inez group of Oligocene-Miocene age. Wells usually bottom at 8,000 to 10,000 feet in the Merecure group of upper Eocene age (chart 1, column W). Petroleum is produced mainly from the two lowest members, the Colorado and Amarillo, of the Oficina formation [Mencher and others, (50)]. The Colorado member consists predominantly of shales with some fine- and coarse-grained sandstone.

El Roble field

Of the formations penetrated in El Roble field, only the Freites and Oficina formations, and sometimes only the Oficina formation, were gamma-ray logged. The gamma-radioactivity in all wells examined (table 7) was regular with no abnormal peaks shown on the logs. In the Colorado member of the lower part of the Oficina formation, gamma-ray activity was slightly higher than in the upper part of the formation but not consistently so. An average of the gamma-ray activity represented by the peaks would be about 0.003 percent approximate equivalent uranium.

Other fields

The gamma-ray logs examined in the other fields of this area, Santa Ana, Santa Rosa, Guario, San Roque, Rincón Largo, Toco, Guere, Soto, and Mapire were similar to those in El Roble field. Logging depths range from 4,000 to 10,000 feet and include the Colorado and Amarillo members of the lower part of the Oficina formation (chart 1, column W). The log of well G-30 in the Guario field has several peaks in the Colorado member that are equivalent to about 0.004 percent approximate equivalent uranium. In the Soto field the log of well SV-3 had a maximum deflection,probably also in the Colorado member, equivalent to about 0.006 percent approximate equivalent uranium.

The record of radioactivity on all the gamma-ray logs in the San Joaquín-Guario area is regular and with only a few small peaks. The highest peaks observed represent from about 0.003 to 0.004 percent approximate equivalent uranium with the exception of the higher peak in the Soto field previously mentioned.

In La Vieja field, about 35 kilometers northeast of the Guario field, wells penetrate in general the same section of Oligocene-Miocene rocks discussed above but the units are thinner, a characteristic of near-shore deposition. The gamma-ray log of well La Vieja-3 extends to 2900 feet with only a slight peak on the gamma-ray curve representing about 0.003 percent approximate equivalent uranium in the lower part, probably La Pica formation of middle Miocene age.

The Greater Oficina area

South of the San Joaquín-Guario area but still within the State of Anzoátegui, is the Greater Oficina area that includes a group of fields: Oficina, Chimire, Guico, Nipa, Caico Seco, Boca, Dación, Leona, and Areo. Of the numerous wells in these fields, 33 gamma-ray well logs were examined.

The Greater Oficina area lies on the north-dipping southern limb of the Maturín basin. The stratigraphic section penetrated in the wells [Hedberg and others (76)] consists mainly of the shallow-water-marine, brackish-water, and continental beds of the Oficina formation of Oligocene age, and the Freites formation of middle Miocene age (chart 1, column W). According to Mencher, and others (50), all oil, to date, has been produced from sands of the Oficina formation. These units are interbedded glauconitic and carbonaceous sandstones and shales. The Oficina formation contains numerous thin beds of lignitic coal.

The wells in most fields extend to depths of 5,000 to 6,000 feet although those in the Nipa and Leona fields are as much as 10,000 feet deep. In most cases gamma-ray logs were made only of the lower 500 to 2,000 feet of hole, which interval generally corresponds to the thickness of the oil-producing zone of the Oficina formation.

The Oficina, Chimire, Guico, and Nipa fields

In the Oficina field the logs of wells OG-151 and OG-300 show very regular radioactivity. In well OG-300 the highest gamma-ray activity represents an average of about 0.005 percent approximate equivalent uranium.

In the Chimire field, the average gamma-ray highs are equivalent to from 0.002 to 0.004 percent approximate equivalent uranium. In the log of well CHV-60 R there is a sharp gamma-ray high equivalent to about 0.006 percent approximate equivalent uranium.

The Guico field, represented by logs of wells GV-21, GV-26, GV-28, GV-67, and GV-68 (table 7), is similar to Chimire in depth drilled and in gamma-ray activity. Average gamma-ray highs represent about 0.003 percent approximate equivalent uranium and only one gamma-ray peak represented as much as 0.006 percent.

The wells of the Nipa field extend to depths of 10,000 feet and are deeper than other wells of the area, but otherwise, the gamma-ray logs are very similar. The higher deflections represent from about 0.003 percent to 0.004 percent approximate equivalent uranium. The oscillating record of radioactivity recorded on the 12 gamma-ray logs examined seems to correspond well to the known series of thinly laminated strata that vary abruptly over short distances.

The small gamma-ray highs found in this area probably represent glauconitic and carbonaceous shale and lignitic beds that are normally slightly more radioactive than sandstones and limestones.

North central Venezuela

In north-central Venezuela, 41 wells were examined in the fields of Las Mercedes, Lechosa, Tucupido, Sabán, and Ruiz.

In general the wells of this area extend to depths of 5,000 feet and bottom in the Temblador formation of Upper Cretaceous age. Unconformably above the Temblador formation lies the productive marine to brackish-water interbedded lignitic sandstone and shales of La Pascua formation of Oligocene age [Mencher and others, (50)]. The formations of Eocene and Paleocene age are missing, and the overlying Roblecito and Chaguaramas formations of Oligocene and Oligo-Miocene ages extend to the surface (chart 1, column Q).

At Las Mercedes field a correlatable gamma-ray high was apparent in wells M-8, M-131, and M-159 at depths of about 4,570 feet, 4,510 feet, and 4,550 feet, respectively. This peak, equivalent to about 0.004 percent approximate equivalent uranium, is relatively definite and lies near the top of the Temblador formation. It is logged as a calcareous sandstone, and may be phosphatic.

In the Lechosa field, a gamma-ray log of well Lechosa-2, showed a slight peak in the gamma-curve at about the same depth as the peaks in the Las Mercedes field; the peak represents about 0.003 or 0.004 percent approximate equivalent uranium.

In the other fields of the area, the six gamma-ray logs examined reflect equally weakly radioactive rocks; average gamma-ray activity is about 0.003 percent or less approximate equivalent uranium.

The record of gamma radioactivity of the Roblecito shale in all these logs is very even and regular. The log of the radioactivity of the Pascua formation of similar age is irregular but of the same general magnitude. The log of gamma-radioactivity of the Temblador (Cretaceous) is very irregular, a characteristic that may be caused by the interbedded glauconitic beds in this formation.

Eastern part of the State of Falcón

In the Cumarebo field of eastern Falcón, the log of well-117 was examined. This log was a record of the Caujarao and Mosquito formations of Miocene age (chart 1, column L) that consist, according to Mencher and others (50), of interbedded shales and fine-grained sandstones. The log was a poor one for rectification but it displayed no gamma-ray deflections that would suggest abnormal radioactivity.

Bolívar coastal fields

In the eastern Maracaibo basin, the numerous coalescing shore line and lake fields are grouped together and commonly referred to as the Bolívar coastal fields [Mencher and others (50), and staff of Shell Caribbean Petroleum Company, (46)]. Gamma-ray logs were examined of the Mene Grande, Bachaquero, Lagunillas, and Tia Juana fields.

The stratigraphic section is complete and comprises rocks from Recent to middle Cretaceous age, the latter of which overlie basement rock at about 14,000 feet [chart 1, column C; Sutton, (44), and Mencher, and others (50)]. The structure is a monocline dipping gently southwestward. Most of the oil is produced from the Lagunillas formation of Miocene age, from the La Rosa formation of Oligo-Miocene age, and from the Icotea formation of Oligocene age. Most of the wells seem to bottom in the Potreritos (Paují) formation of Eocene age at about 5,500 to 6,000 feet with gamma-ray logs usually recording the full depth of the hole.

In Tia Juana field, the logs of wells TJ-223, TJ-225, TJ-226, and TJ-447 were checked. The gamma-ray logs, in general, portray a low but regular level of radioactivity, although there are slight gamma- ray highs in the La Rosa and Potreritos formations that seem to correlate between adjacent wells. The Potreritos formation according to Mencher and others (50), is chiefly composed of dark gray to black carbonaceous sandy shales and white oil-stained sandstones deposited under brackish-water to shallow marine conditions. La Rosa formation (Oligo-Miocene) is composed of green-gray clayey shales in the lower part, and of sandy shales interbedded with thin lignites and zones rich in carbonaceous material in the upper part.

The Lagunillas field

Wells in Lagunillas field penetrate a section similar to that in the Tia Juana and Bachaquero fields. Most of the wells are shallow and bottom in the Potreritos formation (Eocene) at about 6,000 feet. The Lagunillas formation (Miocene) is composed of interbedded shales, sands and lignites, deposited apparently in alternating brackish and fresh water (Mencher, idem). The lower Lagunillas sands form the reservoir for most of the heavy petroleum produced in the Bolívar coastal fields. Between the lower and upper sand lies a zone of bleached and mottled clay bands, lignites, and black carbonaceous sticky clays that probably originated as swamp muck (idem).

Gamma-ray logs are regular with few peaks in gamma-ray intensity. Several small peaks reflect from the Lagunillas and Potreritos formations in all wells. In wells LL-434, and LL-447, a relatively high peak represents a black shale of La Rosa formation.

Other fields

In the Bachaquero field, south of Lagunillas field, the log of well Lagunillas-19 shows gamma-ray peaks in the Lagunillas formation between 100 and 130 feet above the La Rosa contact. The greatest gamma-ray deflection is 8.1 inches on a 10-inch sensitivity scale and, therefore, represents about 0.006 percent approximate equivalent uranium. The radioactivity probably reflects the carbonaceous zone of Lagunillas formation. The Miocene formations in Bachaquero field are normally low in gamma-ray activity.

At Mene Grande field, the short gamma-ray log of well MG-415 extends from 2,150 to 3,410 feet, and shows only gentle broad peaks with maximum deflection equivalent to about 0.003 percent approximate equivalent uranium.

Northwestern part of the State of Zulia

In the northwestern part of the State of Zulia, between Lake Maracaibo and the Perijá Mountains, the major oil fields are Mara, La Paz, and La Concepción. Gamma-ray logs were examined from these fields, and also from Macoa, Rio del Sarro and Alturitos fields. The stratigraphic sequence covered by gamma-ray well logs in this area is restricted usually to the Colón, La Luna, and Cogollo limestone formations of Cretaceous age, that are the principal oil-producers. The dark massive shales of the Colón formation are characteristically low in gamma-ray activity and the curves very regular. The dark bituminous limestones and shales of La Luna formation are uniformly more radioactive, and are reflected on the gamma-ray curve as a plateau that represents about 0.004 percent approximate equivalent uranium, or twice the normal radioactivity. Upon this plateau are superimposed several sharp peaks of much greater amplitude. The peak at the base of La Luna, which is usually the most prominent, is a correlation unit for wells all over the western Maracaibo basin and, due to an abundance of phosphatic fish remains, has been termed the "fish-bone bed". The radioactivity of this bed, usually 10 to 20 feet thick, ranges from 0.005 to 0.014 percent approximate equivalent uranium. (See section on Radioactive shaly limestone in western Zulia.)

The massive highly fossiliferous gray limestone of the Cogollo formation is generally only weakly radioactive, although small gamma-ray peaks usually are shown on the gamma-ray logs. These peaks represent about 0.004 percent approximate equivalent uranium except in well Rabán-14 of Mara field where one peak represents 0.006 percent.

Mara field

The "fish-bone bed" is the least radioactive, about 0.004 percent approximate equivalent uranium, in wells Rabán-3 and Rabán-4 of the Mara field.

Well Rabán-12.--In well Rabán-12, the log of the "fish-bone" bed represents about 0.008 percent approximate equivalent uranium. Two other gamma-ray peaks in La Luna formation represent about 0.005 percent approximate equivalent uranium. These three sharp, narrow peaks in gamma-ray intensity are illustrated in figure 21.

Well Rabán-14.--In well Rabán-14, basal La Luna formation is very high in gamma-ray activity--0.011 percent approximate equivalent uranium.

Well Rama-1.--In well Rama-1, located in the central part of the Mara field, a complete gamma-ray log was made of the entire Cretaceous sequence. On the log the plateau of radioactivity of La Luna formation is well displayed between the lower levels of radioactivity recorded in shale of the younger Colón formation and the massive limestone of the older Cogollo

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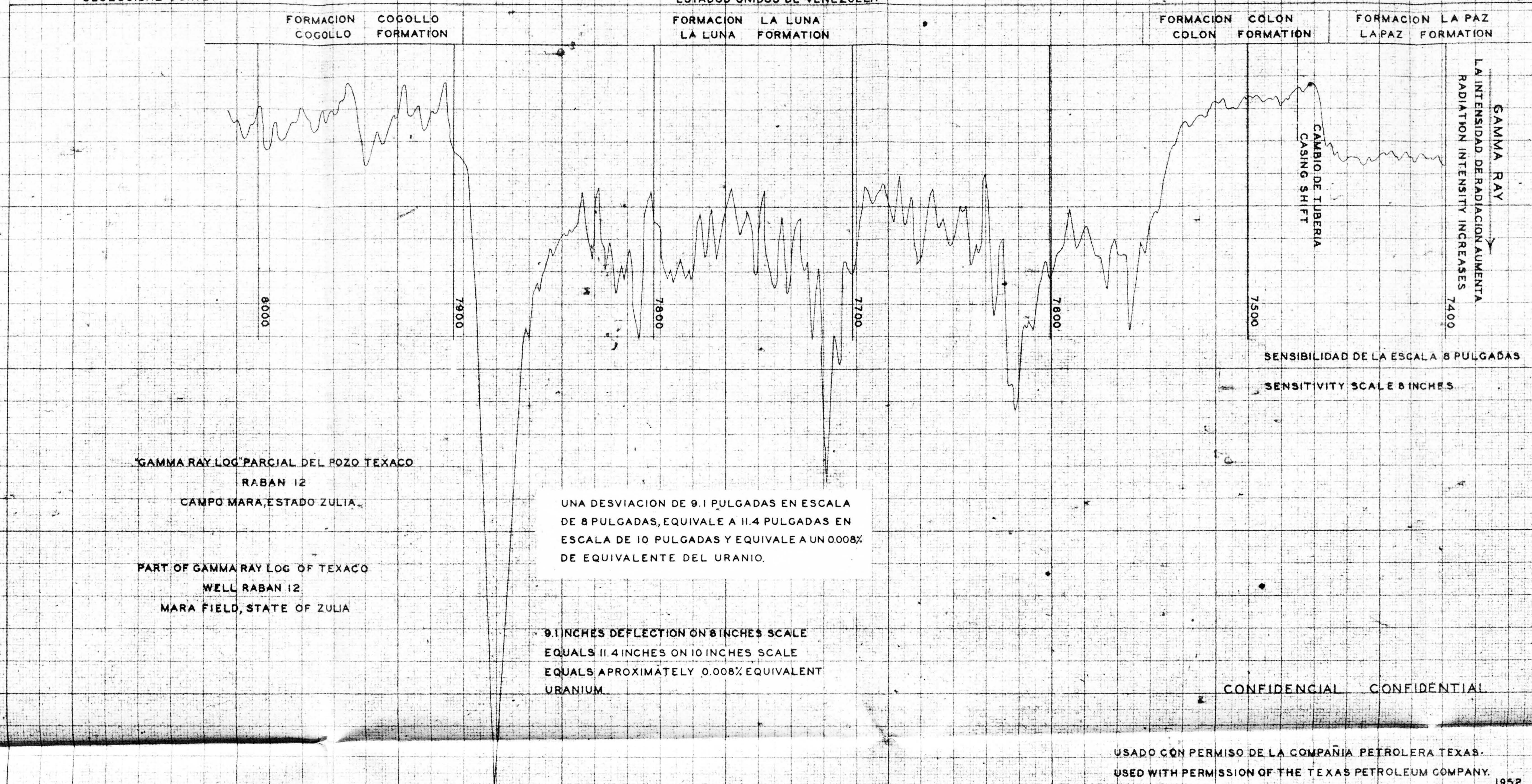
FIGURA 21



(Capacho) formation. The log of the basal "fish-bone" bed of La Luna formation represents about 0.014 percent approximate equivalent uranium. The well was completely cored and samples of this radioactive zone were taken for study. See table 4.

One sample of the most radioactive bed is a dark gray fine-grained, fossiliferous limestone. A thin-section shows abundant calcareous microfossils of Globulina and Gumbelina in a ground mass of carbonaceous clay. Numerous fish scales in this sample have been altered to a bluish-white mineral, probably vivianite, an hydrous phosphate of iron. A chip of this same sample contained 0.008 percent equivalent uranium by radiometric analysis. All the core samples were analyzed in the Trace Elements Section Washington Laboratory of the United States Geological Survey. The results are listed in table 4, and discussed in the section of the report on Radioactive shaly limestone in the western part of the State of Zulia.

Wells MA-2 and MA-9.--Wells Ma-2 and Ma-9 are east of the axis of the main Mara structure; consequently La Luna formation is much deeper, from 10,490 to 10,520 feet. The maximum deflection of the basal bed here is 12.8 inches at 10-inch sensitivity scale or about 0.009 percent approximate equivalent uranium.

La Paz field

La Paz field is southwest of the Mara field and along the same structural trend. Gamma-ray logs of wells P-101 and P-114 show the same gamma-ray plateau of La Luna formation with an anomolous peak at the base. In well P-114 the gamma-ray deflection of the "fish-bone bed" was about 18.5 or more inches at a 10-inch sensitivity scale, which represents more than 0.013 percent approximate equivalent uranium. The gamma-ray log of this part of the formation is shown in figure 22. Samples of the core of this section were also sent to the Trace Elements Section Washington Laboratory for analysis. Samples contain from 0.002 to 0.030 percent equivalent uranium and from 0.002 to 0.027 percent uranium. The Cogollo (Capacho) formation in La Paz field reflects several small sharp gamma-ray peaks as it does in wells in the Mara field. One peak, representing about 0.005 percent approximate equivalent uranium, is slightly higher than the average of La Luna.

Other fields

In the abandoned fields of Rio del Sarro and Macoa, at the base of the Perijá Mountains, southwest of La Paz field, wells Z-20-1, and Z-25-1, and Zulia 25-1 penetrate rocks of Cretaceous age that are broken by normal faulting. La Luna formation, however, is still evident as a gamma-ray high with the greatest deflection just above the contact with the Cogollo formation. These gamma-ray logs were perhaps the oldest logs examined as these fields were the earliest found in the Maracaibo area. Consequently, log data were insufficient for evaluation of deflections.

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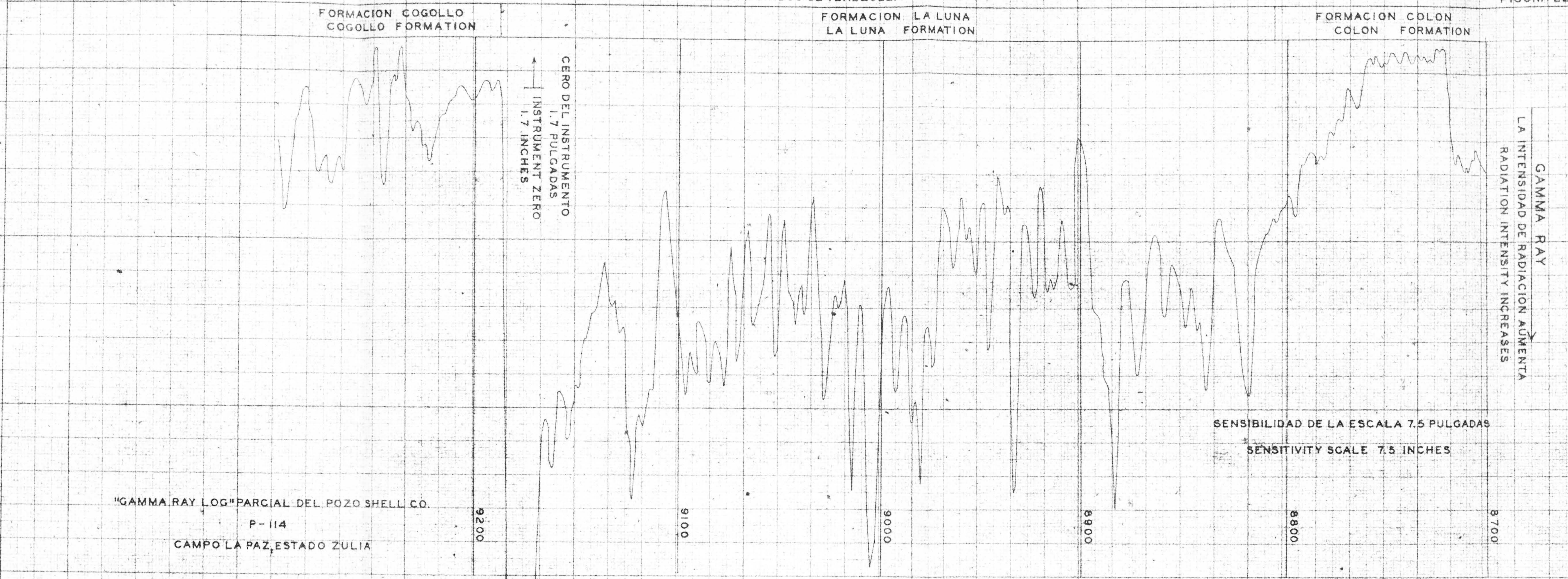
FIGURA 22



"GAMMA RAY LOG" PARCIAL DEL POZO SHELL CO.
P-114
CAMPO LA PAZ, ESTADO ZULIA

PART OF GAMMA RAY LOG OF SHELL
WELL P-114
LA PAZ FIELD, STATE OF ZULIA

UNA DESVIACION DE UNAS 14 PULGADAS
EN ESCALA DE 7.6 PULGADAS, EQUIVALE A
UNAS 18.5 PULGADAS EN ESCALA DE 10 PULGADAS
Y EQUIVALE A UN 0.013 DE EQUIVALENTE DEL
URANIO.

ABOUT 14 INCHES DEFLECTION ON 7.5 INCH
SCALE EQUALS ABOUT 18.5 INCHES ON 10 INCH
SCALE AND EQUALS ABOUT 0.013% EQUIVALENT
URANIUM.

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In the Alturitas wildcat well, AIT-2, southwest of Macoa field, the Cretaceous rocks are very deep. The well bottomed in the Cogollo formation at a depth of 15,820 feet. Here also the entire La Luna formation is reflected as an irregular plateau on the gamma-ray log with the highest deflection at the base of the formation.

The Barinas area

The Barinas area, in the State of Barinas, is near the foot of the southeast slope of the Venezuelan Andes. Company competition is keen in the area, and consequently, little data were available. The gamma-ray logs of three wells were examined, Silvan-2, -3, and -6.

These wells bottom in the Fortuna (Mito Juan) formation of Upper Cretaceous age (chart 1, column H). The Fortuna consists of limestone with thin beds of black fossiliferous shales and sandy glauconitic shales; the dark glauconitic shale contains abundant fish scales. Stratigraphically above the Fortuna formation is the Esperanza formation also of Cretaceous age. Although no very prominent gamma-ray deflections are shown in the logs, low gamma-ray peaks are registered on the logs of the Fortuna formation in well Silvan-3, and on the log of the Misoa formation (Eocene) in well Silvan-2. In well Silvan-6 similar low peaks are registered on the gamma-ray record of the Misoa formation and again in glauconitic sand of the Fortuna formation. There is also another slight increase in the gamma-ray activity in the Esperanza formation.

Oil well gas analyses

Helium and free hydrogen may be of radiogenic origin and the presence of either gas may, therefore, be indicative of radioactive source material. In an attempt to determine if either helium or hydrogen occurs in Venezuela, several of the oil-producing companies were questioned about reservoir gas analyses. Although it was the general opinion that analyses for helium had never been made, it was the general belief that helium does not occur in the fields of Venezuela.

The Texas Company, through the courtesy of Mr. Everett Dobson, donated general analyses of gas samples from various parts of the country. The various constituents include the gaseous paraffins (methane group), and small amounts of CO_2, but neither helium nor hydrogen. The constituent gases comprise 100, or slightly more than 100 percent of the total, and there is, therefore, little room for other constituents, if the analyses are reliable. One sample from the central part of the State of Guárico contained less than half a percent free nitrogen.

Conclusions and recommendations

Gamma-ray well logs represent an abundance of data about the radioactivity of the materials logged, and where available, afford a relatively simple means of radiometric reconnaissance in themselves. The data may also be used to direct field examination, or to calculate reserves of low-grade ore. It is concluded from this preliminary study that: 1), La Luna formation in the western part of the State of Zulia is of the greatest interest because of its significantly higher average level of radioactivity (about 0.004 percent approximate equivalent uranium); 2), only thin zones in other formations in other parts of the country reach or exceed this level of radioactivity, and they are, at least for the present, not of such interest; 3), additional study is required.

It is, accordingly, recommended that more study of gamma-ray logs be done in the western part of the State of Zulia, and that, in general, the gamma-ray log program be continued, and expanded.

In western Zulia, more gamma-ray logs of the bituminous fossiliferous radioactive shale and limestone of La Luna formation, and particularly of the basal phosphatic, more highly radioactive "fish-bone" beds need to be examined to aid in the economic evaluation of the rock. For the same reasons more thorough study should be made of all gamma-ray logs available and of those new logs that become available in the future. The study should be coupled with the petrographic, chemical, and spectrographic examination of well-core and outcrop samples and a general geologic study of La Luna formation in the Maracaibo basin.

The general gamma-ray log program should be continued and expanded in order to obtain radiometric data from other areas, as well as to obtain more complete data about those areas scanned in this preliminary survey. Gamma-ray logs of wells should be examined as they become available. Core samples of abnormally radioactive rocks that have been gamma-ray logged should be analyzed radiometrically to establish a better calibration of gamma-ray log deflections to percent equivalent uranium, or verify that used now.

In the study, a system of recording data should be developed, such as tabulating well number, field, depth and magnitude of greatest deflections in inches and also percent approximate equivalent uranium, general radioactivity of the formation or unit, and remarks. This data might be later arranged in a compilation chart showing the relative radioactivity of rocks of northern Venezuela, and applied to correlation studies and the continued search for uranium deposits.

To facilitate the compilations, arrangements should be made to obtain new logs as they become available and to study the ones already available. The Petrotec Company, in particular, has shown an interest and willingness to cooperate and will probably continue, if requested, to call attention to abnormally radioactive zones as indicated on gamma-ray logs and also to aid in interpreting the logs.

SUMMARY OF URANIUM POTENTIALITIES OF VENEZUELA

Although much more study is required before an authoritative appraisal of the uranium potentialities of Venezuela can be made, we feel that the results of the present investigation are sufficiently definite to warrant an evaluation of rock types and areas that contain uranium and in which further work should be done. More reconnaissance should, of course, be done, examining representative black shales, phosphates, continental deposits of red bed type, crude oils, placers, and mineral deposits.

Uranium has been found in Venezuela in the following rocks and areas, listed in order of potential economic value:
1) In phosphatic "fish-bone" shales of the basal Colón formation and basal La Luna formation in the State of Trujillo and the western part of the State of Zulia, respectively;
2) In Quaternary or Recent alluvial deposits near Ciudad Bolívar, State of Bolívar; at Santa Catalina, Territory Delta Amacuro; from several localities in Territory Amazonas; and in the "black sand" beds in the basal part of the Roraima series at Peraitepuy, Gran Sabana, State of Bolívar;
3) In the pegmatites of Mérida and Timotes, State of Mérida, and in pegmatitic facies of the Archean (?) basement complex near Ciudad Bolívar.

In addition to these rocks and areas, a specimen of sandstone impregnated with the yellow secondary uranium mineral autunite (?) or schroeckingerite (?) was seen that is reported by its finder, Dr. V. S. Paulik, to come from the "red beds" of the La Grita-Seboruco area, State of Mérida. Hot springs of Las Trincheras, State of Carabobo, and Las Fuentes, near Ureña, State of Táchira are radioactive, but most of the radioactivity is probably caused by thorium and its decomposition products, rather than by uranium. The metalliferous deposits examined have not been notably radioactive but more work is needed before they could be classed as nonradioactive, and it is pitchblende deposits that are currently in greatest demand.

The phosphatic shales of the Colón and La Luna formations offer promise of large tonnages of relatively low-grade uranium ore, with the possibility of byproducts such as shale oil, calcium phosphate, and metals such as molybdenum, rare-earths, and nickel. The grade of samples taken ranges from 0.003 to 0.03 percent equivalent uranium, 0.002 to 0.027 percent uranium, and areas of higher-grade ore may be found by additional work.

The radioactive heavy minerals zircon, monazite, samarskite (?), and probably others as yet unidentified, occur in a sufficiently great number of placer deposits to suggest that still richer concentrations may be found. Radioactivity may be caused largely by thorium--rather than uranium-series elements, but even so, it might be possible to segregate sufficient material as a byproduct of large-scale gold or diamond dredging operations to merit stockpiling.

The pegmatites have never been large-scale producers of uranium, and it is unlikely that the uraniferous pegmatites either of the State of Mérida or of the Brazilian shield in the State of Bolívar will be of economic importance, even as byproducts producers in large-scale operations, because none of the pegmatites seen appear to contain enough other minerals of sufficient economic value to warrant large-scale operation. Residual placers derived from these pegmatites might be of economic interest, but they too, would probably need the presence of other valuable constituents to be worth mining.

If the occurrence of secondary uranium minerals in the "red beds" of the La Grita-Seboruco area, State of Mérida is confirmed, then all areas underlain by La Quinta and Tomón formations in the Andes and possibly in the Perijá Mountains of the State of Zulia are potential host rock for uranium deposits of the carnotite or copper-uranium type, and a search for such deposits should be started. Such deposits, if of sufficient grade and tonnage, would rank first in the economic graduation of uranium deposits in Venezuela. Another "red bed" sequence, that of the rocks of the Roraima series in the Gran Sabana, also merits additional study for carnotite or copper-uranium deposits.

In summary, the uranium potentialities of Venezuela seem to be excellent for large low-grade deposits of phosphatic shale; fair for low-grade placer concentrates; poor for hydrothermal metalliferous deposits of the Katanga, or Great Bear Lake type; it is highly possible that "red bed" deposits of the carnotite or copper-uranium type will be found.

RECOMMENDATIONS

The recommendations discussed below are made with the premise that the program of study of radioactive material started by the Dirección Técnica de Geología of the Ministerio de Minas e Hidrocarbúros of the Estados Unidos de Venezuela will actively continue. With this in mind, the search for fissionable material can be undertaken in two ways, 1), by ammassing and evaluating data on the radioactivity of any or all rocks, soils, and fluids in the country, and 2), by searching in specific mines, areas, or rock types, chosen on the basis of geologic favorability, or selected from the reports of prospectors. The two methods are not mutually exclusive and much data of both general and specific use may be obtained from either. It is assumed that the program will continue to be administered on a sound geologic basis. That is to say, in the administration of the program, sound geologic theory should be the basis for the thoughtful application of the ever-increasing knowledge of the distribution of uranium, and of the processes that cause the distribution of uranium in the earth's crust.

Amassing data

Much valuable data regarding the radioactivity of rocks and fluids in Venezuela could be obtained relatively simply by scanning, radiometrically, collections of samples; by expanding the gamma-ray log program; by enlisting the aid of other competent field men both in the Dirección Técnica de Geología and in allied governmental agencies; and by enlisting the aid of the general public.

Examining collections

More than 90 percent of the data obtained from any mass program, such as determining the radioactivity of the 90,000 samples in the laboratory of the Creole Petroleum Corporation in Caracas, is bound to be negative, that is, more than 90 percent of the samples will be of normal or sub-normal radioactivity. Yet, if the data are adequately measured and recorded, negative data can be of considerable use both in tentatively outlining rocks and areas that need not be examined further, and in establishing the normal radioactivity of the rocks of Venezuela. In this particular case it is probable that by carefully studying available gamma-ray logs, samples can be chosen for radiometric analysis, thus eliminating many areas and most of the 90,000 samples from consideration.

Other rock collections that might also merit radiometric examination are those of other governmental agencies, of colleges, and of other oil companies. Still another source of information amenable to mass-sampling methods is crude oil or gas, samples of either of which should be readily available. In any such large-scale program, great care should be taken to obtain reliable data, and a laboratory scaler should be used on uniform samples.

Continuing and expanding the gamma-ray log program

A second general method of rapidly obtaining a mass of information about the radioactivity of source materials in Venezuela is by the continued study of gamma-ray logs. By means of gamma-ray logs and suitable core samples approximate estimates may be obtained of the radioactivity of the materials penetrated by the wells and recorded on the logs. Inasmuch as many hundreds of gamma-ray logs have been and are being used in most of the major oil-producing areas, it should be possible to obtain sufficient data so that estimates could be made of the normal radioactivity of most of the sedimentary rocks in northern Venezuela. The discovery of abnormally radioactive fluids or rocks, such as the "fish-scale" bed in western Zulia, and their subsequent study in the field and laboratory would, of course, be an essential byproduct of the study.

The section in this report discussing gamma-ray logs clearly indicates that a more general program should follow this preliminary study. In the general program, gamma-ray logs of a greater number of wells, of wells that penetrate more, and of more representative stratigraphic sections should be examined. A suitable system of collating information would record information already available and keep abreast of new gamma-ray logs. It should be kept constantly in mind that geologic data are required in addition to purely physical radiometric data in order to arrive at any sound conclusions regarding the distribution of uranium in the rocks and fluids of Venezuela. A wealth of subsurface information could be obtained during this program that would help place uranium in its proper geologic perspective.

Using Geiger counters

General radiometric data and, possibly, specific positive information, could be readily obtained if those members of the Dirección Técnica de Geología engaged in field work would use Geiger counters in the field. The onerous chore might be lightened somewhat by recalling that radioactive beds, such as the phosphatic shales of Chejendé, or the group of pegmatitic gneisses near Ciudad Bolívar, could be traced and mapped by means of their radioactivity.

Although the unit studying radioactive materials is properly established in the Dirección Técnica de Geología, information could be obtained by other agencies of the government. For example, competent mining engineers of the Dirección de Minas could obtain invaluable geologic and radiometric data about some areas they examine, and submit it to the Dirección Técnica de Geología.

Interesting and enlisting the aid of the public

A fourth source of both specific and general data is the general public. If it were generally known that samples were welcome, that the discovery of uranium would not be penalized but rewarded, and that scientific studies open to comment and criticism were to be published, much more information would undoubtedly be forthcoming.

By free analyses

One means of encouraging the general public to give information would be to establish a policy of free analysis of samples submitted. The radiometric equipment now installed in the laboratory of the Dirección Técnica de Geología is adequate for routine radiometric analyses. This equipment should be supplemented by the installation of minimum facilities in the Laboratorio Nacional to make chemical analyses of radioactive elements. The results of the radiometric analyses should be given to the person submitting the sample.

By clarifying or revising the laws

During the course of field work we have talked with at least four mining men who have stated that they are neither interested in searching for, nor want to find uranium because all radioactive source material is a national reserve and of no value to them; and, moreover, they are subject to penalties for searching for it. One of these men stated that the discovery of uranium in a gold mine, for example, would probably force the closing of the mine. Another "had heard" that it was illegal to import Geiger counters. The validity of these statements is only pertinent in so far as the present mining law is restrictive. It is not our intention in this report, or even within our sphere of knowledge, to suggest specific changes in the law, but it would appear desirable, as suggested by Larson (13), for the government to clarify its position either by amending or by revising present laws so as to protect the legitimate interests of Venezuela and still encourage the search for uranium. A further stimulus that might be considered in this regard, is the offering of a bonus for the discovery and/or production of ore of certian types and minimum uranium content. Parenthetically, the offer of such a bonus by the Atomic Energy Commission in the United States of America may have done more to stimulate the general search for uranium than any other single step taken, even though no one, up to at least June 1951, had ever fulfilled the terms imposed and collected the bonus.

By publication

Another important method of encouraging the active search for uranium by persons not officially connected with the governmental program is that of publication. In the first place, it seems highly desirable, in view of the many misconceptions commonly held, to publish a statement giving the general position of the government relative to radioactive material. Such a statement should not be delayed until after laws may be revised, or a bonus offered, or a more elaborate program established, but should be issued now, and other statements issued later as conditions change or as the situation warrants. In the second place, it is strongly recommended that the results of geologic examinations be published soon after completion of each examination. The prompt publication of such studies would encourage and direct discussion, as well as increase the morale and usefulness of the geologists.

1) Publication would encourage open, informed discussion among geologists, mining engineers, prospectors, and other interested people and thereby further the government's program.

2) Published papers could, by careful treatment, indicate subjects that could be freely discussed and those that could not, thereby directing discussion and establishing and clarifying a security program. Regarding security, the underlying principle of protecting governmental interest could be fully satisfied by preparing reports in two parts, one of general geology for publication containing all information except average grade, available tonnage, and economic potentialities; the other, for governmental use covering only these three itemized "sensitive" items.

3) Prompt publication of geologic studies completed would tend to sustain or increase morale by giving the writers professional recognition, the chance to benefit from the discussion of informed readers, and the experience and obligation of collecting data with publication in mind. It would also serve notice that the program of investigation of radioactive source materials in Venezuela of the Dirección Técnica de Geología is on a sound basis and actively functioning. As a start, it might be a good idea to publish parts of this report, and of some of the other reports of radiometric studies previously made by members of the Dirección Técnica de Geología.

Searching in specific areas

As byproducts in the accumulation of a mass of information concerning radioactivity in Venezuela would be the discovery of specific areas or rocks meriting additional study. In addition to this source of specific information, geologic experience suggests that there are some favorable rock types that should be examined for uranium. Another source of specific information is, of course, hints and rumors from prospectors, the press, and others.

Examining favorable rock types

As discussed in the introduction to this report, some rocks that may be regarded as preferred host rocks for uranium deposits are: terrestrial sandstone and conglomeratic beds of "red bed" type such as the Roraima series, and especially cupriferous "red bed" formations such as La Quinta and Tomón formations; heavy minerals in sands, especially those derived from felsic granitic rocks such as the granitic rocks of the Andes and of parts of the Brazilian shield; thin black shales and all marine phosphatic beds, such as the phosphatic "fish-bone" beds of the Colón and La Luna formations; coals and other carbonaceous deposits, especially impure lignites beneath unconformities, thucholite;base-metal gold or silver mines, especially those with siliceous or Felsic granitic wall rocks. In addition to these, other materials that merit examination in any radiometric reconnaissance are hot spring waters, crude oils and gases, and residual-clay soils. In the reconnaissance investigations reported in this paper we have been guided, in general, by these favorable rock types. Radiometric reconnaissance should continue in other parts of the country, and should likewise be guided by these and any other favorable rock types discovered in the program of amassing data or reported elsewhere in the world. For example, a reconnaissance for radioactive source materials in the eastern part of Venezuela should include, among other possibly radioactive source materials, the black shales of the Barranquín formation, many coal beds, the hot springs at El Pilar, the asphaltite of Guanoco, stream and beach sands, and representative oil refinery samples.

Investigating hints and rumors

Even though most of the hints and rumors of uranium discoveries prove to be false or exaggerated, the discovery of one good clue among ten investigated, far outweighs the disappointment of the nine bad ones. As an example, if the discovery of uraniferous sandstone in the Andes reported by Dr. V. S. Paulik is authenticated: then the cupriferous La Quinta and Tomón formations in the States of Táchira, Mérida, Trujillo and perhaps western Zulia are definitely established as potential host rocks for uranium; in addition, other uranium deposits of the carnotite or copper-uranium type may be found by intensive prospecting.

Among the hints and rumors of uranium deposits in Venezuela currently available are the following:
1) Charles Beech, lumberman, associated with the Amacuro Mining Company reports that a Geiger counter registered abnormal radioactivity in the pre-Cambrian rocks along the "Siberian fault zone" that was traced from British Guiana into the southern part of the Territory Delta Amacuro. The analyses of samples reportedly taken were supposed to have been given to the writers but have not been received.
2) Dr. V. S. Paulik, prospector, reported to us the occurrence of green and yellow uraniferous ore from the Five Star district in British Guiana between the Barama and Barima Rivers. This area would be just east of the boundary between the Territory Delta Amacuro and the State of Bolívar, and in the same general area as that of Mr. Beech's report.
3) A letter received from Dr. Pedro Guzmán, Sección Bella Vista 145, Maracaibo, stated that pitchblende and monazite sand had been found in the sands of Lake Maracaibo (see section in this report titled Beach sands of Maracaibo). Dr. Pedro Guzmán Bufaete, of Caracas states that the letter came from his father, now dead for 4 years, and that any investigators should contact his brother, Dr. Emiro Guzmán Rivero, telephone 2011, Apartado de Correos 83, Maracaibo.
4) Newspaper articles have reported uranium in the swimming pool of the Country Club at Barcelona, in Los Monjes islands, and most recently, reported in the paper Ultimas Noticias, March 8, 1952, on Margarita Island.
5) Other hints can be gained by studying the geologic literature and applying the principle of geologic favorability. For example, many of the descriptions of rocks in the Andes contain references to either phosphatic beds, black shales, or cupriferous sandstones, all of which should be examined radiometrically in any thorough study of radioactive source materials.

Concentration of future work

The results of our investigations suggest that more thorough geologic and radiometric investigations should be made of the phosphatic "fish-bone" beds of the Maracaibo basin and probably in the Andean States, of the cupriferous La Quinta and Tomón formations in the Andes, and of the more felsic rocks of the Venezuelan Guayana, Territory Delta Amacuro, and State of Bolívar.

In the Maracaibo Basin

The work recommended on the phosphatic "fish-bone" bed is: more reconnaissance; field-mapping and sampling; and a general geologic study of the region. Reconnaissance is required to determine more exactly the approximate limits of the uraniferous beds that we have found in the Mara field, State of Zulia and near Chejendé, State of Trujillo. Field mapping and sampling of the uraniferous beds are required to give more exact knowledge of extent, thickness, and uranium content. In the western Zulia region these data can be supplemented by much information available from well cores and well logs, especially gamma-ray logs. A general geologic study making use of isopach and isofacies maps of the Colón and La Luna formations in the Maracaibo basin should be initiated. The goals of the study would be to determine the distribution and reasons for occurrence of the abnormally radioactive beds, so that others might be found. Here too, much data could be obtained from well cores and logs, although it would require personnel experienced in subsurface geology and stratigraphy.

In the Andes

The first work required in the La Quinta and Tomón formations is to check the reported occurrence of uraniferous sandstone on the rio Agaraveca near La Grita. Regardless of the authenticity of the occurrence all the areas currently being examined for copper in these rocks should be examined radiometrically. If the occurrence is authenticated, then more weight might well be given to the investigation of radioactivity than to the search for copper, and the deposit should be mapped in detail and physically explored.

In future radiometric studies in the Andean region, pegmatites, felsic igneous rocks, and hydrothermal metal deposits should be examined.

In the Guayana

The more Felsic rocks of the Brazilian shield in the Venezuelan Guayana may warrant additional geologic study even though the known radioactivity is caused by the group of pegmatitic rare-earth-thorium minerals that are not generally considered to be good sources of uranium.

The study in the northern part of the State of Bolívar could be based on the maps made from the aerial photographs flown in conjunction with the aero-magnetometer survey, and should take advantage of the portable radiation meters of high counting-rate. In this regard, it might be of interest to examine more closely the cost of commercial airborne radiometric surveys, for most of the first terraine north and west of the Gran Sabana is ideal for the low-level flights required. Information about airborne surveys could be obtained from Frank W. Stead (79).

In the more detailed study of individual areas such as the Cerro Toribio--Rio Claro area, or the Ciudad Bolívar area, a suitable end product would be not simply the geologic mapping of the area, nor simply a record of radioactivity, but an integrated study combining and interpreting both.

In addition to these specific areas, much radiometric reconnaissance in this vast region remains to be done. It is not suggested that exploratory expeditions in search of uranium alone be organized, but it is suggested that any expeditions organized for other purposes should be equipped with Geiger counters and accompanied by geologists trained in their use and maintenance. Furthermore, the search for uranium should be considered as one of the purposes of the expedition. In geologic studies of the Guayana it would be wise to examine radiometrically the basal beds of the Roraima series and many more mineral deposits.

Facilities required

For the proper functioning of the program of search for radioactive source material in Los Estados Unidos de Venezuela, laboratories and a collating and collecting unit are required. Such facilities, at least for the present, need not be large nor require additional personnel.

Laboratories

The radiometric equipment brought from the United States Geological Survey's Radiation Laboratory in Denver, and now installed in the Caracas laboratory of the Dirección Técnica de Geología is probably sufficient for the current needs of the present program. It would be desirable to have more portable rate meters of the type that are sealed against tropical dampness. As an approximate guide to the number required, two for each field party, one for use and one for a spare set should be sufficient. The repair of Survey meters in the field is not recommended. Probes of high counting rate, such as the 20- and 40-inch probes, are very useful in field surveying; inasmuch as the useful life-term of these probes is determined by the total number of pulses received, additional probes are required.

Maintenance facilities are perhaps adequate for simple repair of the portable rate meters now on hand. If more are obtained, and if the laboratory scaler needs repairing, the services of an expert technician will be required. If a technician is hired, it is recommended that he be sent for instruction to the Radiation Section, Geophysics Branch, U. S. Geological Survey in Washington, D. C. (Stead 79). As an alternative to hiring a technician, it might be advisable to make arrangements with a reliable radio repair shop for more elaborate repairs, or for that matter, for the standard maintenance of all the radiometric equipment including the ordering of tubes, batteries, etc.

There is at present no laboratory in Caracas that is equipped to make chemical analyses for uranium or thorium. Dr. J. L. Prado, Director of the Laboratorio Nacional, has affirmed his interest in training one or two chemists in analytic procedures, and in obtaining a minimum amount of equipment necessary for making routine chemical analyses for radioactive elements. It is, therefore, recommended that two chemists of the Laboratorio Nacional be sent to the U. S. Geological Survey's Trace Elements Section Laboratory in Washington D. C. for instruction in methods, techniques, and equipment required.

Collecting and collating unit

The unit for collecting and collating data need not be large but should be given no other assignments. That is to say, the job requires the full-time of at least one, and preferably two geologists. The part-time assistance of other specialists such as petrographers or geologists familiar with certain areas will continue to be needed. Methods of collating the data obtained should be devised so that information is readily available and the filing system capable of expansion. Preparation of reports for publication of both laboratory and field studies is strongly urged as a very good way to keep data in hand, available, and therefore useful, and the preparation of reports for restricted circulation of information regarding average grade, tonnage, chemical processes, etc. is similarly recommended for this type of data.

One indispensable adjunct to the organization would be a library. The published papers brought down with the two senior writers for the use of the Dirección Técnica de Geología would serve as a nucleus for the library, which could be gradually built up by the addition of other pertinent books, pamphlets, and articles.

General comments

It would, obviously, be desirable for the chief of the Unit charged with the responsibility of studying radioactive source materials in Venezuela to have a first-hand knowledge of some uranium ore deposits. It is suggested, therefore, that he be sent to the United States of America to examine some of the black shale, phosphate, carnotite, copper-uranium, and pitchblende deposits. It might also be considered desirable for him to examine some of the lode uranium deposits of Columbia.

It is the considered opinion of Wyant and Sharp that the chief of the unit should be an experienced field geologist with a wide knowledge of general geology and geologic processes, and especially versed in stratigraphy and subsurface geology. He should be assisted by at least one less-experienced geologist who is familiar with prospecting techniques.

In conclusion, the U. S. Geological Survey, and Wyant and Sharp, in particular, will continue to be interested in the developments of the program and stand ready to give what advice, aid, and assistance they can.

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