DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH
DIVISION OF BIOLOGY AND MEDICINE
U.S. ATOMIC ENERGY COMMISSION

GEOPHYSICAL INVESTIGATIONS
MAP GP-525

CORRELATION OF AERORADIOACTIVITY AND GEOLOGY

The natural gamma aeroradioactivity of Puerto Rico ranges between 50 and 800 cps (counts per second). More than three-fourths of the island has a radioactivity of 300 cps or less, and the central part of the island is in general slightly more radioactive than the margins. An area several miles wide that extends southeastward from San Sebastián for about 25 miles has a radioactivity of 300 to 800 cps.

The central mountainous portion of Puerto Rico consists principally of volcanic breccia, flows and tuffaceous siltstone, sandstone, and conglomerate. According to Mitchell (1954), the most common extrusive rocks, both flows and tuffs, are andesitic. Most of the rocks in central Puerto Rico are of Cretaceous age, and some are of early Tertiary age. These rocks have been extensively folded and faulted. Most of the major faults strike from west to northwest.

North and south of the central mountainous area are belts of younger geologic units. These younger units can be separated into (1) formations of Tertiary age consisting mostly of limestone and marl with beds of sandstone and clay, and (2) unconsolidated to friable deposits of sand, gravel, clay, and silt, mostly of Pleistocene to Recent age. The Tertiary formations in general strike east, parallel to the mountainous backbone of the island.

Two large plutons of granodiorite to dioritic composition occur in the southeastern and west-central parts of the island and an elongated body of serpentinite occurs in the southwestern part.

The generalized geology shown on the accompanying map was modified from Briggs (1964). The geology and the radioactivity of the 14 geologic units are discussed more fully in another report (MacKallor, in press).

The unit of tuff, volcanic breccia, and flows (Kv) has a radioactivity of 100 to 200 cps, except for two areas of 200 to 300 cps east and northeast of San Lorenzo. Radioactivity of the unit of sandstone, siltstone, and conglomerate (Ksr) is mostly 200 to 300 cps. That of several areas in the central part of the island is 300 to 500 cps, and in one small area along a major east-trending fault (Briggs, 1964) near the exact center of the island is 650 cps.

The unit of siltstone, sandstone, and volcanic rocks (Ts) occurs only in small patches and its radioactivity is 100 to 300 cps. That of the unit of sandstone, conglomerate, and volcanic rocks (TKs) is mostly 100 to 300 cps. In most places there is no correlation between radioactivity contacts and the geologic contacts of this unit. However, seven miles north-northeast of Mayagüez two small areas having radioactivity of 300 to 400 cps within this unit contrast with the adjacent unit (Ksr). Radioactivity of the San Sebastián Formation (Tss) is 100 to 300 cps.

Radioactivity of the Lares Limestone (Tl) is 200 to 700 cps. The higher count is found west of 66° 45' W. longitude. Other Tertiary formations, mostly limestones, also are slightly more radioactive west of that meridian. Limestones in general have radioactivity of less than 500 cps. The reason for the high radioactivity in part of the Lares and other formations in northwestern Puerto Rico is not known, but the high radioactivity may be coming from insoluble residues in the karst topography formed by weathering of the limestones. Some of the areas of high radioactivity are within five miles of a known intrusive, and although it is possible that some of the high radioactivity may be coming from unmapped intrusives, this is not likely as the known intrusives do not have as high a radioactivity as some of the nearby areas of limestone. The limestones may have an usually high potassium content, and potassium-40 and other radionuclides may be concentrated in soil as calcium carbonate is weathered from the parent rock. Southeast of San Sebastián where the contact between the San Sebastián Formation and the Lares Limestone correlates with a change in radioactivity, the clays of the San Sebastián generally are 100 to 200 cps and the Lares is 400 to 500 cps. Normally clay is comparatively more radioactive than limestone.

Radioactivity of the Cibao Formation (Tcb) is mostly 200 to 500 cps. Eight miles northeast of San Sebastián that of part of the Cibao is 600 to 800 cps and is the most radioactive area detected in Puerto Rico. This area of relatively high radioactivity is a continuation of the radioactive highs associated with the Lares Limestone.

The Aguada Limestone (Tag) has a radioactivity of 100 to 300 cps east of 66° 45' W. longitude; to the west its radioactivity is mostly 200 to 400 cps, with some slightly higher. The Camuy Formation and Aymamón Limestone (Tca) mostly yield 200 to 300 cps; in the northwestern corner of the island an area of these units is 300 to 400 cps. The Ponce Limestone and the Juana Díaz Formation (Tpj) occur only in southern Puerto Rico and have a very limited areal extent. Their radioactivity is 100 to 200 cps.

Radioactivity of the unit of sand and clay (QTsc) is 100 to 300 cps. That of the unit of silt, sand, clay, and gravel (Qd) is mostly 100 to 200 cps, and in some areas is 200 to 300 cps.

Near Mayagüez in southwestern Puerto Rico there are several small and one large area of serpentinite. Although some of the serpentinite has radioactivity of 100 to 300 cps, it is mostly less than 100 cps and is the lowest radioactivity measured in Puerto Rico.

Plutonic rocks (TKp) are widespread throughout Puerto Rico but with two exceptions are too small to be significant to this interpretation. The northern part of the San Lorenzo batholith in southeastern Puerto Rico has been mapped by Broedel (1961). The rock is granodiorite except for very minor amounts of diorite and gabbro along the margin of the batholith. The northern and eastern parts of the batholith have a radioactivity of 200 to 400 cps which contrasts with the 100 to 200 cps of the intruded Cretaceous rocks. In the southwestern part of the batholith radioactivity is generally 100 to 200 cps and does not contrast with the intruded rocks. Possibly the southwestern quarter of the batholith contains more diorite and gabbro and less granodiorite, hence less potassium feldspar than the other parts of the batholith.

The Utuado pluton trends northwestward for more than 20 miles in west-central Puerto Rico. According to Weaver (1958), this pluton consists mainly of granodiorite and quartz diorite with minor amounts of quartz porphyry and gabbro along the margins. Granodiorite, which contains megascopically visible orthoclase, forms the central mass of the pluton, and the quartz diorite, which does not contain visible orthoclase, crops out along the western and southeastern sides (Weaver, 1958, pl. 1). The central part of the pluton is 300 to 600 cps in radioactivity, and the marginal areas are 200 to 300 cps, the same as the surrounding host rock. The granodiorite in the central part of the pluton shows a higher radioactivity than the marginal quartz diorite, probably because the percentage of orthoclase is higher in the granodiorite than in the quartz diorite and the host rocks.

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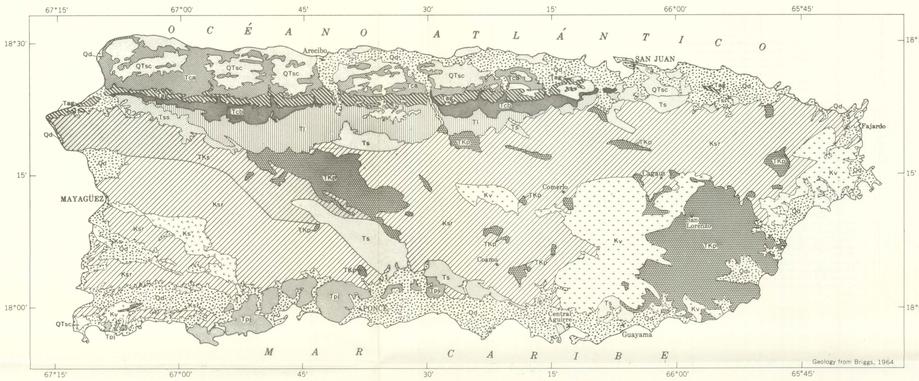


GENERALIZED GEOLOGIC MAP

SCALE 1:480 000

10 0 10 20 MILES

10 0 10 20 KILOMETERS

EXPLANATION

Pleistocene and Recent

Qd — Silt, sand, clay, and gravel deposits
Includes floodplain and terrace deposits of sand, silt, clay, and gravel; swamp and marsh deposits consisting mostly of organic muck; and beach and dune deposits consisting largely of calcite, quartz, and fragments of volcanic rocks

Miocene to Recent

QTsc — Sand and clay
Principally present in the northern coastal plain and in the areas of karst topography

QUATERNARY

TERTIARY TO QUATERNARY

Miocene

TCa — Camuy Formation and Aymamón Limestone
Camuy consists of punky fragmental limestone and marl with some sandstone and hard limestone beds, some discontinuous dolomite beds. Maximum thickness about 600 feet
Aymamón is thick-bedded, dense limestone which grades upward into punky limestone and marl; discontinuous beds of dolomite near top. Total thickness may exceed 1200 feet

Tag — Aguada Limestone
Thick-bedded dense limestone interbedded with chalky limestone and marl; locally thin-bedded near top. From 100 to 450 feet thick

Northern Puerto Rico

Oligocene

Tcb — Cibao Formation
Interbedded marl, chalk, and limestone; some beds of sand, clay, and conglomerate. Maximum thickness of 1000 feet

Tl — Lares Limestone
Thick-bedded limestone. Maximum thickness about 1000 feet

Tss — San Sebastián Formation
Beds of sand and clay; conglomerate near base; some lenses of limestone. Maximum thickness exceeds 1000 feet

Tpj — Ponce Limestone and Juana Díaz Formation
Ponce Limestone consists of an upper member of thick-bedded limestone and a lower member of thin- to medium-bedded limestone. Upper member contains beds of shale; lower member contains beds of shale and sandstone. Juana Díaz Formation consists of shale, sandy limestone, and conglomerate

Southern Puerto Rico

TERTIARY

Pliocene and Pre-Pliocene

Ts — Siltstone, sandstone, and volcanic rocks
Rocks deposited in a marine environment. Limestone beds near base. Volcanic rocks include tuff and andesite. Unit includes some intrusive rocks

Upper Cretaceous

Ksr — Sedimentary rocks
Predominantly sandstone, siltstone, and conglomerate of volcanic origin deposited in a marine and sub-aerial environment. Unit includes tuff, volcanic breccia, extrusive rocks, and some lenses of limestone

Lower Cretaceous

Kv — Tuff, volcanic breccia, and flows
Most rocks deposited in a marine environment; some subaerial volcanic rocks. Unit includes some amphibolite, lenses of limestone, and thin-bedded sandstone and siltstone. Some strata of Late Cretaceous age may be included within this map unit

TKs — Sandstone, siltstone, conglomerate, and volcanic rocks
Unit contains some limestone. Volcanic rocks consist of tuff, flows, and breccia

TERTIARY

CRETACEOUS

INTRUSIVE ROCKS

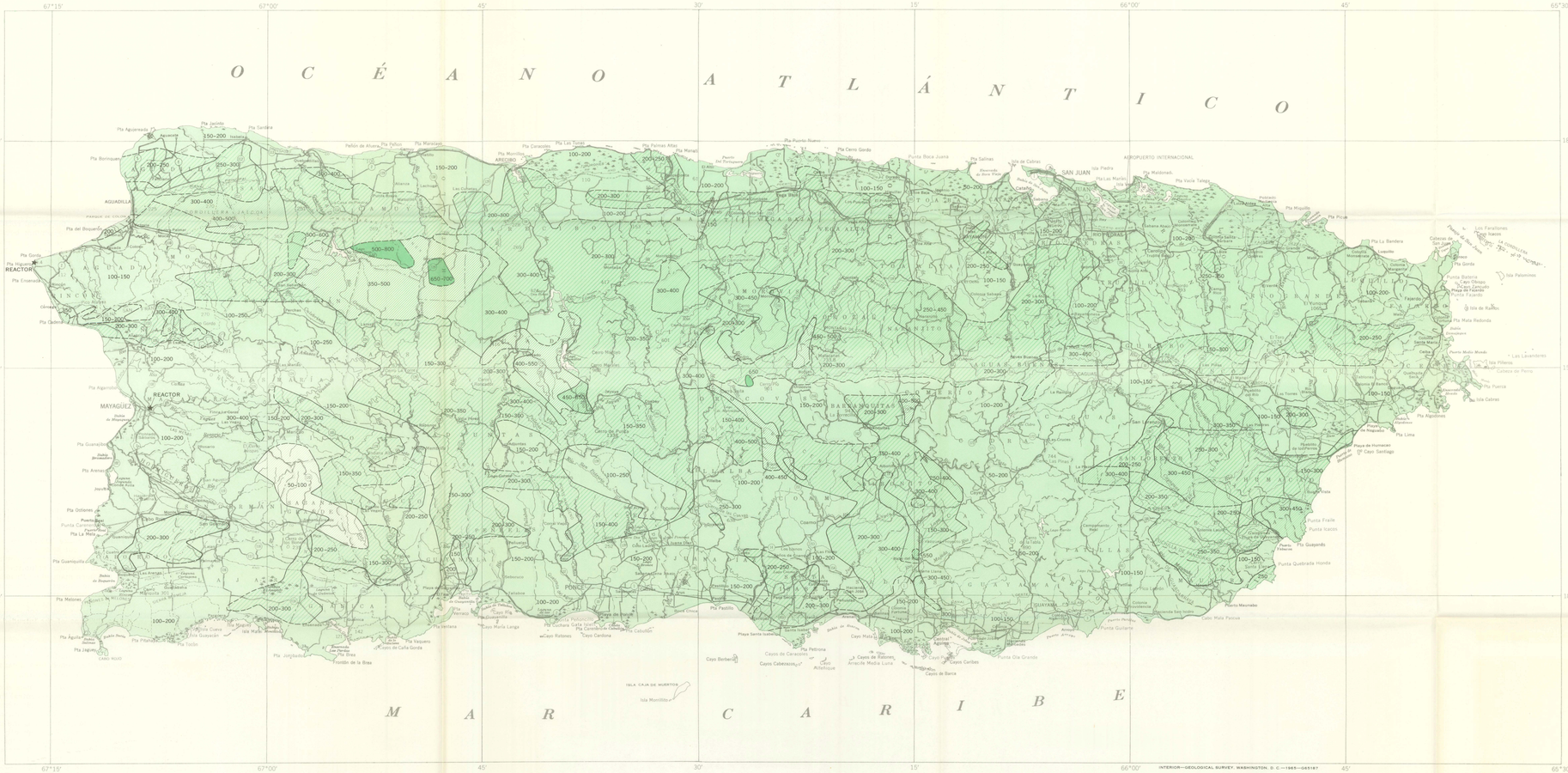
TKp — Plutonic rocks
Granodiorite, quartz diorite, quartz monzonite, and diorite

CRETACEOUS AND TERTIARY

Ks? — Serpentinite
Serpentinized peridotite

CRETACEOUS?

Contact



Base by U.S. Geological Survey

NATURAL GAMMA AERORADIOACTIVITY MAP OF PUERTO RICO

By
Jules A. MacKallor

SCALE 1:240 000

10 5 0 10 MILES

10 5 0 10 KILOMETERS

1965

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1965—GES167

Aeroradioactivity survey flown at 500 feet above the ground under the direction of J. L. Meuschke, 1961

EXPLANATION

100–250 / 200–250 — Radioactivity boundary
Solid where well defined, dashed where transitional. Numbers indicate aeroradioactivity in counts per second

Less than 100 | 100–200 | 200–300 | 300–400 | 400–500 | 500–600 | 600–700

Generalized levels of aeroradioactivity in counts per second

★ Location of reactor site

EXPLANATORY TEXT

An aeroradioactivity survey of the island of Puerto Rico was made between Nov. 12 and Dec. 3, 1961. The survey was made with continuously recording scintillation-detection equipment (Davis and Reinhardt, 1957) installed in a twin engine aircraft, and was flown along east-west flight lines spaced one mile apart at approximately 500 feet above the ground. Topographic maps were used for pilot guidance, and the flight path of the aircraft was recorded with a continuous-strip-film camera. When the aircraft passed over recognizable features, fiducial edgemarks were made simultaneously on the film and on the radioactivity and altimeter charts.

The radioactivity data were compensated for deviations from the 500-foot surveying elevation by signals from the radar altimeter. The scintillation equipment measures only gamma radiation with energy levels greater than 50 kev (thousand electron volts), and the results are recorded in cps (counts per second). The effective area of response of the scintillation equipment at an elevation of 500 feet above the ground is an area approximately 1000 feet in diameter.

The gamma-ray flux at 500 feet above the ground has three principal components: (1) cosmic radiation, (2) radionuclides in the air, and (3) radionuclides in the upper few inches of the ground. The cosmic component is measured two or more times daily at 2000 feet above the ground, and the scintillation equipment is adjusted to subtract the cosmic effects from the radioactivity record. Measurements of the cosmic component also were obtained at the beginning and end of each flight line, when the aircraft was at 500 feet above water and at least 500 feet from land.

The component due to radionuclides in the air (mostly radon daughter products) at 500 feet above the ground is difficult to evaluate. It is affected greatly by meteorological conditions; but if no survey lines are flown during conditions of extreme inversion or during and immediately after thundershowers, the air component does not obscure radioactivity levels that reflect changes in the ground component.

The ground component consists of gamma rays from natural radionuclides (principally members of the uranium and thorium radioactivity decay series and potassium-40) and from fallout from atomic testing. The radioactivity measured in Puerto Rico is quite low, and the component due to fallout, if any, is small, as the lowest total radioactivity measured is 50 cps. The distribution of the naturally occurring radionuclides in the surficial rocks and soil is reflected by the radioactivity which in some areas can be correlated directly with geology.

Some boundaries between areas of different radioactivity become obscure or disappear and terminate without enclosing an area of distinct radioactivity. Such occurrences are generally due to lithologic changes within a geologic unit or obscuring of geologic boundaries by a lithologically similar cover of soil. In addition to the specific radioactivity units shown in black on the map, the entire area has been divided by 100-cps increments into seven generalized levels of radioactivity which are shown by the green patterns.

REFERENCES

Davis, F. J., and Reinhardt, P. W., 1957, Instrumentation in aircraft for radiation measurements: Nuclear Sci. and Eng., v. 2, no. 6, p. 713-727.