MASTER

528
CEX-59.4.12

CIVIL EFFECTS STUDY

AERORADIOACTIVITY SURVEY AND AREAL
GEOLOGY OF THE PITTSBURGH AREA,
PENNSYLVANIA, OHIO, WEST VIRGINIA,
AND MARYLAND (ARMS-I)

Robert G. Bates

This document is
PUBLICLY RELEASABLE
Hugh Kinser
Authorizing Official
Date: *8/5/08*

Issuance Date: September 1966

**CIVIL EFFECTS TEST OPERATIONS
U.S. ATOMIC ENERGY COMMISSION**

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

Printed in USA. Price \$1.00. Available from the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U. S. Department of Commerce, Springfield, Virginia 22151.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

AERORADIOACTIVITY SURVEY AND AREAL GEOLOGY OF THE PITTSBURGH AREA, PENNSYLVANIA, OHIO, WEST VIRGINIA, AND MARYLAND (ARMS-I)

By
Robert G. Bates

Approved by: Director
U. S. Geological Survey

Approved by: L. J. DEAL, Chief
Civil Effects Branch

U. S. Geological Survey
and
Division of Biology and Medicine, USAEC
September 1964

NOTICE

This report is published in the interest of providing information which may prove of value to the reader in his study of effects data derived principally from nuclear weapons tests and from experiments designed to duplicate various characteristics of nuclear weapons.

This document is based on information available at the time of preparation which may have subsequently been expanded and re-evaluated. Also, in preparing this report for publication, some classified material may have been removed. Users are cautioned to avoid interpretations and conclusions based on unknown or incomplete data.

ABSTRACT

During the summer of 1960 ^{was made} the U. S. Geological Survey made ^{an} an airborne radioactivity survey of a large area in western Pennsylvania, eastern Ohio, northern West Virginia, and western Maryland. The survey area, totaling 14,400 square miles, is centered on the greater Pittsburgh metropolitan area. ^{2/} The survey was made on behalf of the U. S. Atomic Energy Commission as part of its Aerial Radiological Measurement Surveys (ARMS-I) program, a program of airborne radioactivity surveys of nuclear installations within the United States. Within the survey area are the Shippingport, Bettis, Apollo, Cheswick, and Waltz Mill nuclear facilities.

No. 9) Radioactivity levels range from 150 to 900 cps (counts per second) and average between 500 and 600 cps. Strata of Permian age have the highest radioactivity level and those of Mississippian age the lowest. Appalachian structural trends are reflected by linear radioactivity units in the southeastern corner of the survey area. *6 references.*

CONTENTS

ABSTRACT	5
1. INTRODUCTION	9
1.1 Location and Purpose of Survey	9
1.2 Airborne Survey Procedure	9
1.3 Scintillation Detection Equipment	10
1.4 Compilation of Aeroradioactivity Data	12
1.5 Theoretical Considerations	12
2. GENERAL GEOLOGY	12
3. DISTRIBUTION OF AERORADIOACTIVITY	15
3.1 Pittsburgh Survey Area	15
3.2 Shippingport Reactor Site	15
4. AERORADIOACTIVITY AND AREAL GEOLOGY	15
REFERENCES CITED	17
ADDITIONAL REFERENCES	19

ILLUSTRATIONS

FIGURES

1. Location of Pittsburgh Survey Area	10
2. Diagram of Airborne Radioactivity Survey Equipment	11
3. Generalized Geologic Map of Pittsburgh Survey Area	14

ILLUSTRATIONS (Continued)

4. Airborne Radioactivity Survey, Shippingport Facility,
Pennsylvania 16
5. Radioactivity of the Geologic Units in the Pittsburgh
Survey Area 18

PLATE

1. Natural Gamma Aeroradioactivity Map of the Pittsburgh
Area, Pennsylvania, Ohio, West Virginia, and Maryland .. in pocket

AERORADIOACTIVITY SURVEY AND AREAL GEOLOGY OF THE PITTSBURGH AREA, PENNSYLVANIA, OHIO, WEST VIRGINIA, AND MARYLAND (ARMS-I)

1. INTRODUCTION

1.1 Location and Purpose of Survey

The Pittsburgh survey area covers parts of western Pennsylvania and Maryland, northern West Virginia, and eastern Ohio (Fig. 1). The survey, consisting of 14,400 square miles, is centered on the greater Pittsburgh metropolitan area, and includes the Shippingport, Bettis, Apollo, Cheswick, and Waltz Mill nuclear facilities.

Between June 14 and Sept. 2, 1960, the U. S. Geological Survey, on behalf of the Division of Biology and Medicine of the U. S. Atomic Energy Commission, made an airborne radioactivity survey of the Pittsburgh area. This survey was part of the Aerial Radiological Measurement Surveys (ARMS-I) program, a program of airborne radioactivity surveys of nuclear installations in the United States. The purpose of the survey was to determine the natural radioactivity level of the rocks and soils. This information will serve as a reference to determine the amount and extent of any increase in radioactivity level of the area by the various nuclear facilities, either through normal operations or from any accidents that may occur. Another purpose of the survey was to determine the relation between the distribution of radioactivity and the various geologic units within the area.

1.2 Airborne Survey Procedure

The survey was made with scintillation-detection equipment installed in a twin-engine aircraft. Parallel north-south flight lines were flown at one-mile intervals. The plane maintained an approximate altitude of 500 ft above the ground and an air speed of 150 mph. Topographic maps were used for pilot guidance. The flight path of the aircraft was recorded by a gyrostabilized continuous-strip-film camera, and the distance of the aircraft from the ground was measured by a continuously recording radar altimeter. Fiducial markings (providing a common reference for the radioactivity and altimeter data and the

camera film) were made with an electromechanical edgemark system operated by the observer when the aircraft passed over recognizable features on the ground.

The gamma-ray flux at 2000 ft above the ground, which comes from cosmic radiation and to a much lesser extent from radionuclides in the air, except after nuclear tests, is measured twice each day while surveying. This quantity is called the cosmic background at 2000 ft. Theoretically, the cosmic background at 500 ft is nine-tenths that at 2000 ft, and the radioactivity data have had this nine-tenths of the cosmic component removed. The cosmic background during the survey of the Pittsburgh area ranged from 240 to 470 cps (counts per second).

Fig. 1—Location of Pittsburgh survey area.

1.3 Scintillation Detection Equipment

The scintillation-detection equipment used by the Geological Survey was designed by the Health Physics Division of the Oak Ridge

1.4 Compilation of Aeroradioactivity Data

Flight-line and check-point locations from the strip film exposed during the survey were plotted on compilation base maps at a scale of 1 in. equals 1 mile (1:63,360). The altitude-compensated radioactivity profiles for each flight line were examined and points of change or breaks in radioactivity level were selected. These points of change in radioactivity level along the flight line were plotted on the base map. Corresponding changes on adjacent lines were connected to form radioactivity units; the units were assigned values, in counts per second, reflecting the range of fluctuations in radioactivity level within the unit. The compilation base maps were reduced to a scale of 1 in. equals about 4 miles (1:250,000), and the data were transferred to maps of the Army Map Service 1:250,000 topographic map series. The final map thus produced (Pl. 1) shows radioactivity levels and points of change in level and sufficient culture and drainage features for orientation in the field. This map has also been published by the Geological Survey⁴.

1.5 Theoretical Considerations

From the standpoint of airborne radioactivity surveys, only three naturally occurring radioactive elements and their daughter products are important. They are uranium, thorium, and K^{40} . Only those radionuclides that decay by gamma-ray emission can be detected and measured with scintillation equipment used in airborne surveys.

Sakakura⁵ has developed equations that relate airborne radioactivity data, semiquantitatively, to the radioactivity of the ground surface underlying the aircraft.

Radioactivity measured at the surveying altitude of 500 ft above the ground has three components:

1. Gamma-ray activity from radionuclides in or on the ground.
2. Gamma-ray activity from radionuclides in the air.
3. Cosmic-ray component.

The activity from radionuclides in air, such as radon, cannot always be separated from the activity of the radionuclides on the ground. The radon content of the air is variable. Minimum values occur on windy days with high barometric pressure or very wet ground conditions. These radon values can increase by a factor of 10 under conditions of low barometric pressure and strong temperature inversion.

The ground component comes from the surface and the upper few inches of the ground and consists of gamma rays from natural radionuclides and fission products in fallout. The distribution of fallout in the Pittsburgh area, if present, is assumed to be uniform and small in amount. This conclusion is supported by the fact that the minimum radioactivity recorded over the area surveyed due to naturally occurring radionuclides and any fallout present was only 150 cps.

2. GENERAL GEOLOGY

The survey area lies within the Appalachian Plateaus physiographic province⁶. Within the survey area this province is further divided

into three sections. They are, from northwest to southeast, the Southern New York section, the Kanawha section, and the Allegheny Mountain section.

Rocks in the survey area range in age from Devonian to Permian. The oldest rocks, argillaceous strata of Late Devonian age, are exposed in the northwestern and southeastern corners of the survey area (Fig. 3). In the northwest corner of the area in Ohio, exposures are limited by extensive glacial deposits. In the southeast corner of the area the strata are exposed along the axes of eroded anticlines. The youngest rocks, cyclic sequences of sandstone, shale, limestone, and coal of Permian age, are exposed in the southern and southeastern part of the survey area. Continental glacial deposits of Pleistocene age overlie bedrock in the northern and northwestern portion of the survey area.

The oldest rocks in the survey area are marine clastic rocks of Late Devonian age. In Ohio these rocks are shale; in Pennsylvania and Maryland graywacke and sandstone are present in addition to shale. Intertonguing with and overlying these marine rocks in Pennsylvania and Maryland are nonmarine shales and sandstones.

The rocks of Mississippian age in the eastern part of the survey area consist of a thick basal sequence of conglomerate and sandstone and some shale. This sequence is overlain by red shale, thin-bedded sandstones, and some limestone. To the west in Ohio the basal Mississippian unit consists of fine-grained sandstone and shale; the upper unit is limestone.

Rocks of Pennsylvanian age are exposed over three-quarters of the survey area. They form a thick column of cyclic strata consisting of sandstone, shale, limestone, and coal. These rocks were deposited in a large sedimentary basin having its axis in southwestern Pennsylvania and northern West Virginia. The basal rocks of Pennsylvanian age are exposed along the margin of the basin in eastern Ohio and northern Pennsylvania. The youngest rocks are exposed along the axis of the basin where the maximum thickness of strata occurs. Marine, brackish, and fresh-water strata are present, indicating fluctuations of the shoreline of the Pennsylvanian sea.

Overlying the rocks of Pennsylvanian age are strata of Permian age. These strata are also composed of cyclic sequences of sandstone, shale, limestone, and coal. However, southward from Wheeling thicker sandstones and red shales, indicative of near-shore and terrestrial environments, replace limestones and gray shales in the upper part of the stratigraphic column.

North of the glacial boundary in Ohio and Pennsylvania the Paleozoic strata are covered in most places by glacial deposits of Pleistocene age. Most of the material in these deposits was derived from nearby bedrock, although some material was transported by the ice from areas in Canada. Glacial outwash filled the valleys of rivers draining the ice front. Most of the outwash deposits have been removed by subsequent erosion and are present only as high terraces on the sides of the valleys.

Geology modified from state geologic maps, Maryland 7, Ohio 8, Pennsylvania 9, and West Virginia 10

5 0 5 10 15 20 25 MILES

Fig. 3—Generalized geologic map of Pittsburgh survey area.

3. DISTRIBUTION OF AERORADIOACTIVITY

3.1 Pittsburgh Survey Area

The natural gamma aeroradioactivity of the survey area ranged from 150 to 900 cps and averaged between 500 and 600 cps. Radioactivity levels were lowest in the glaciated northwestern part of the survey area, where they ranged from 150 to 700 cps and averaged between 350 and 500 cps. Highest values were measured over Permian strata in the southwestern part of the area, where levels ranged from 300 to 900 cps and averaged between 500 and 650 cps. Radioactivity levels over the rest of the area ranged from 150 to 750 cps and averaged between 400 and 500 cps.

Low radioactivity values caused by bodies of water, such as reservoirs and large rivers, are not included in the range of radioactivity values given above.

3.2 Shippingport Reactor Site

The distribution of natural and facility-induced gamma radioactivity of the Shippingport reactor site is shown in Figure 4. The natural radioactivity ranged from 100 to 650 cps and averaged between 500 and 550 cps. It should be noted that some of the radioactivity readings shown on the map are higher than the range of values observed over similar geologic sources elsewhere in the survey area. These higher values result from normal atomic energy operations at the site. Also, the Geological Survey equipment is extremely sensitive to small changes in radioactivity level.

Information on radioactivity levels in the environs and outside the plant boundaries is reported from selected Atomic Energy Commission and contractor installations. This information is reviewed and abstracted for inclusion in the U. S. Public Health Service series of reports entitled "Radiological Health Data". They are issued monthly and can be purchased from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402. Of the five facilities listed in paragraph 1.1, Shippingport and Bettis are operated under Atomic Energy Commission contracts and are included in "Radiological Health Data".

4. AERORADIOACTIVITY AND AREAL GEOLOGY

Little geologic information was obtained from the aeroradioactivity data of the Pittsburgh survey area. Topographic relief made it necessary to fly at a small angle to the regional strike. Also, 75 percent of the area is underlain by sedimentary rocks of Pennsylvanian and Permian age. These sedimentary rocks consist of cyclic sequences of sandstone, shale, limestone, and coal, none of which is thick enough to have an identifying radioactivity level. An additional 20 percent of the area is covered by glacial deposits.

Fig. 4 — Airborne radioactivity survey, Shippingport facility, Pennsylvania.

Some correlation between geology and aeroradioactivity data was noted in the southeastern corner of the survey area. There, radioactivity units of northeasterly trend reflect the general trend of Appalachian stratigraphy and structure. Linear low radioactivity units (150 to 350 cps) reflect carbonate strata of Mississippian age exposed along the crests and flanks of eroded anticlines. Higher values (450 to 650 cps) between the linear radioactivity lows are associated with strata of Devonian age exposed along the axes of the anticlines.

Rocks of Permian age have the highest average radioactivity level, 600 cps, and those of Mississippian age the lowest, 350 cps (Fig. 5). Glacial deposits of Illinoian age have the same average radioactivity level, 500 cps, as rocks of Pennsylvanian age which they overlie and from which they were, in large part, derived. Glacial deposits of Wisconsin age lie to the north of the glacial deposits of Illinoian age and closer to an area of rocks of Mississippian age (Fig. 3). The glacial deposits of Wisconsin age therefore contain a greater proportion of material derived from rocks of Mississippian age than do the glacial deposits of Illinoian age. This is reflected in the radioactivity data; the average radioactivity level of the glacial deposits of Wisconsin age, 400 cps, is intermediate between that of rocks of Mississippian age, 350 cps, and rocks of Pennsylvanian age, 500 cps.

REFERENCES CITED

1. F. J. Davis and P. W. Reinhardt, Instrumentation in Aircraft for Radiation Measurements, Nuclear Sci. and Eng., 2 (6): 713-727 (1957).
2. Kermit Larsen, University of California, Los Angeles, written communication (1958).
3. F. J. Davis and P. W. Reinhardt, Radiation Measurements over Simulated Plane Sources, Health Phys., 8: 233-243 (1962).
4. R. G. Bates, Natural Gamma Aeroradioactivity of the Pittsburgh Area, Pennsylvania, Ohio, West Virginia, and Maryland, U. S. Geol. Survey Geophys. Inv. Map GP-555 (1965).
5. A. Y. Sakakura, Scattered Gamma Rays from Thick Uranium Sources, U. S. Geol. Survey, Bull. No. 1052-A, 50 pp. (1957).
6. N. M. Fenneman and D. W. Johnson, Physical Divisions of the United States, U. S. Geol. Survey, scale 1:7,000,000 (1946).
7. E. B. Mathews, Map of Maryland Showing Geological Formations, Maryland Geol. Survey, scale 1:380,160 (1933).
8. J. A. Bownocker, Geologic Map of Ohio, Ohio Geol. Survey, scale 1:500,000 (1947).
9. Carlyle Gray, Geologic Map of Pennsylvania, Pennsylvania Topo. and Geol. Survey, scale 1:250,000 (1960).
10. J. D. Sisler, Geologic Map of West Virginia, West Virginia Geol. Survey, scale 1:500,000 (1932).

Fig. 5—Radioactivity of the geologic units in the Pittsburgh survey area.

ADDITIONAL REFERENCES

1. Thomas Arkle, Jr., Monongahela Series, Pennsylvanian System, and Washington and Greene Series, Permian System, of the Appalachian Basin, in Geol. Soc. America Guidebook, Pittsburgh Meeting, 1959, p. 143-166 (1959).
2. A. T. Gross and M. P. Schemel, Geology of the Ohio River Valley in West Virginia, in Geology and Economic Resources of the Ohio River Valley in West Virginia, West Virginia Geol. Survey Report XXII, pt. 1 (1956).
3. J. A. Pitkin, S. K. Neuschel, and R. G. Bates, Aeroradioactivity Surveys and Geologic Mapping, in J. A. S. Adams and W. M. Lowder, Editors, The Natural Radiation Environment, Rice University Semcentennial Publications, Chicago University Press, Chicago, p. 723-736 (1964).
4. V. C. Shepps, Glacial Geology of Northwestern Pennsylvania, in Geol. Soc. America Guidebook, Pittsburgh Meeting, 1959, p. 167-188 (1959).
5. V. C. Shepps, G. W. White, J. B. Draste, and R. F. Sitler, Glacial Geology of Northwestern Pennsylvania, Pennsylvania Topo. and Geol. Survey Bull. No. G-32 (1959).
6. C. R. Stauffer and C. R. Schroyer, The Dunkard Series of Ohio, Geol. Survey Ohio, 4th Series, Bull. No. 22 (1920).

EXPLANATION

Explanatory Text

The survey was made with scintillation detection equipment (Davis and Reinhardt, 1957) installed in a two-engine aircraft. Parallel north-south flight lines spaced at one-mile intervals were flown at a nominal altitude of 500 feet above the ground. The flight path of the aircraft was recorded by a gyro-stabilized continuous-strip-film camera. The radioactivity data were compensated for deviations from the 500-foot surveying altitude, and for the cosmic-ray component.

The effective area of response of the scintillation equipment at an altitude of 500 feet is that encompassed by a circle with a radius of 500 feet, and the radioactivity recorded is the average radioactivity of that area. The scintillation equipment records only pulses from gamma radiation with incident energies greater than 50 kev (thousand electron volts). A cesium-137 source is used during periodic calibrations to assure uniformity of equipment response.

The gamma-ray flux at 500 feet above the ground has three principal sources: cosmic radiation, radionuclides in the air (mostly radon daughter products), and radionuclides in the surficial layer of the ground. The cosmic component, called the cosmic background, is determined twice daily by calibration at 2,000 feet above the ground, and is removed from the radioactivity data prior to recording. The cosmic background during this survey ranged from 240 to 470 cps (counts per second).

The component due to radionuclides in the air at 500 feet is difficult to evaluate. It is affected by meteorological conditions, and a tenfold change in radon concentration is not unusual under conditions of extreme temperature inversion. However, if inversion conditions are avoided, the air component may be considered to be fairly uniform on a given day in a particular area, and will not mask the differences in radioactivity levels that reflect changes in the ground component.

The ground component comes from approximately the upper few inches of the ground. It consists of gamma rays from natural radionuclides, principally members of the uranium and thorium radioactive decay series, potassium-40, and fallout of radioactive nuclear fission products. The distribution of fallout in the Pittsburgh area, if present, is assumed to be uniform and small in amount. This conclusion is supported by the fact that the minimum radioactivity recorded over the area due to naturally occurring radionuclides and any fallout present was only 150 cps.

Some correlation between geology and aeroradioactivity data was noted in the southeastern corner of the survey area, where radioactivity units having northeasterly trend reflect the general trend of Appalachian structure. Linear low radioactivity units outline strata of Mississippian age exposed along the crests and flanks of eroded anticlines. High values between the linear radioactivity lows are associated with strata of Devonian age exposed along the axes of the anticlines.

Glacial deposits of Illinoian age in the northern part of the survey area have an average radioactivity level of 500 cps, the same as that of rocks of Pennsylvanian age which they overlie and from which they were, in large part, derived. Glacial deposits of Wisconsin age lie to the north of the glacial deposits of Illinoian age and closer to an area of rocks of Mississippian age. The glacial deposits of Wisconsin age therefore contain a greater proportion of material derived from rocks of Mississippian age than do the glacial deposits of Illinoian age. This is reflected in the radioactivity data; the average radioactivity level of 400 cps for glacial deposits of Wisconsin age is intermediate between 350 cps for rocks of Mississippian age and 500 cps for rocks of Pennsylvanian age.

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

Base from Army Map Service, Corps of Engineers
1:250,000 topographic map series, Canton
(1957), Columbus (1956), Cumberland (1956),
Pittsburgh (1941), and Warren (1957) sheets

PLATE 1-NATURAL GAMMA AERORADIOACTIVITY MAP OF THE PITTSBURGH AREA, PENNSYLVANIA, OHIO, WEST VIRGINIA, AND MARYLAND

By
Robert G. Bates

1966