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CIVIL EFFECTS STUDY

AERORADIOACTIVITY SURVEY AND AREAL GEOLOGY OF THE OAK RIDGE NATIONAL LABORATORY AREA, TENNESSEE AND KENTUCKY (ARMS-I)

Robert G. Bates

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CIVIL EFFECTS TEST OPERATIONS

U.S. ATOMIC ENERGY COMMISSION

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AERORADIOACTIVITY SURVEY AND AREAL GEOLOGY OF THE OAK RIDGE NATIONAL LABORATORY AREA, TENNESSEE AND KENTUCKY (ARMS-I)

By

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ABSTRACT

An airborne radioactivity survey was made of the area around the Oak Ridge National Laboratory near Knoxville, Tenn. The survey area is a square, 100 miles on a side, centered on the town of Oak Ridge. Parallel flight lines totaling 10,000 traverse miles were flown in a northwest to southeast direction at a flight-line interval of 1 mile and an altitude of 500 ft above the ground. The survey was made by the U. S. Geological Survey for the U. S. Atomic Energy Commission as part of its nationwide program of airborne radioactivity surveys of all nuclear installations.

The area is composed of four physiographic subdivisions. They are, from west to east, the Highland Rim, the Cumberland Plateau, the Valley and Ridge province, and the Great Smoky Mountains. The Highland Rim has the lowest average radioactivity level, 300 to 500 cps (counts per second) and the Great Smoky Mountains the highest, 1000 to 1100 cps. Individual geologic units in the Highland Rim, Cumberland Plateau, and the Great Smoky Mountains are not well defined by the radioactivity data. However, the physiographic subdivisions, with the exception of the Highland Rim, can be separated on the basis of radioactivity level or pattern of radioactivity units. In the Pennsylvanian rocks of the Cumberland Plateau the ratio of shale to sandstone and conglomerate increases from southwest to northeast and from northwest to southeast. This is reflected in the radioactivity data in which the radioactivity levels increase in the same directions.

In the Valley and Ridge province, some radioactivity units show continuity along strike completely across the mapped area, a distance of 100 miles. Many show continuity for 50 miles or more. The Rome Formation and the Conasauga Shale of Cambrian age and the Clinch Sandstone of Silurian age are particularly well delineated by the radioactivity data. Middle Ordovician rocks grade from a carbonate sequence on the northwest side of the valley to mostly shale sequence on the southeast side of the valley. The increase in shale content of these rocks to the southeast is reflected by the increasing radioactivity level of these rocks in that direction.

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AERORADIOACTIVITY SURVEY AND AREAL GEOLOGY OF THE OAK RIDGE NATIONAL LABORATORY AREA, TENNESSEE AND KENTUCKY (ARMS-I)

1. INTRODUCTION

1.1 Location and Purpose of Survey

The Oak Ridge National Laboratory (ORNL) survey area is in parts of eastern Tennessee, southeastern Kentucky, and extreme western North Carolina (Fig. 1). The survey area is a square with sides 100 miles long and is centered on the town of Oak Ridge, Tenn. During the spring of 1959, 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 Oak Ridge area. This survey was part of the Aerial Radiological Measurement Survey (ARMS-I) program, a program of airborne radioactivity surveys of all nuclear installations in the United States. The purpose of the survey was to determine the natural radioactivity background of the rocks and soils. This information will serve as a reference to determine the amount and extent of any possible future increase in radioactivity level of the area by the Oak Ridge facility through normal operations or 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 DC-3 type aircraft. Parallel northwest to southeast flight lines oriented normal to the general geologic strike of the area 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

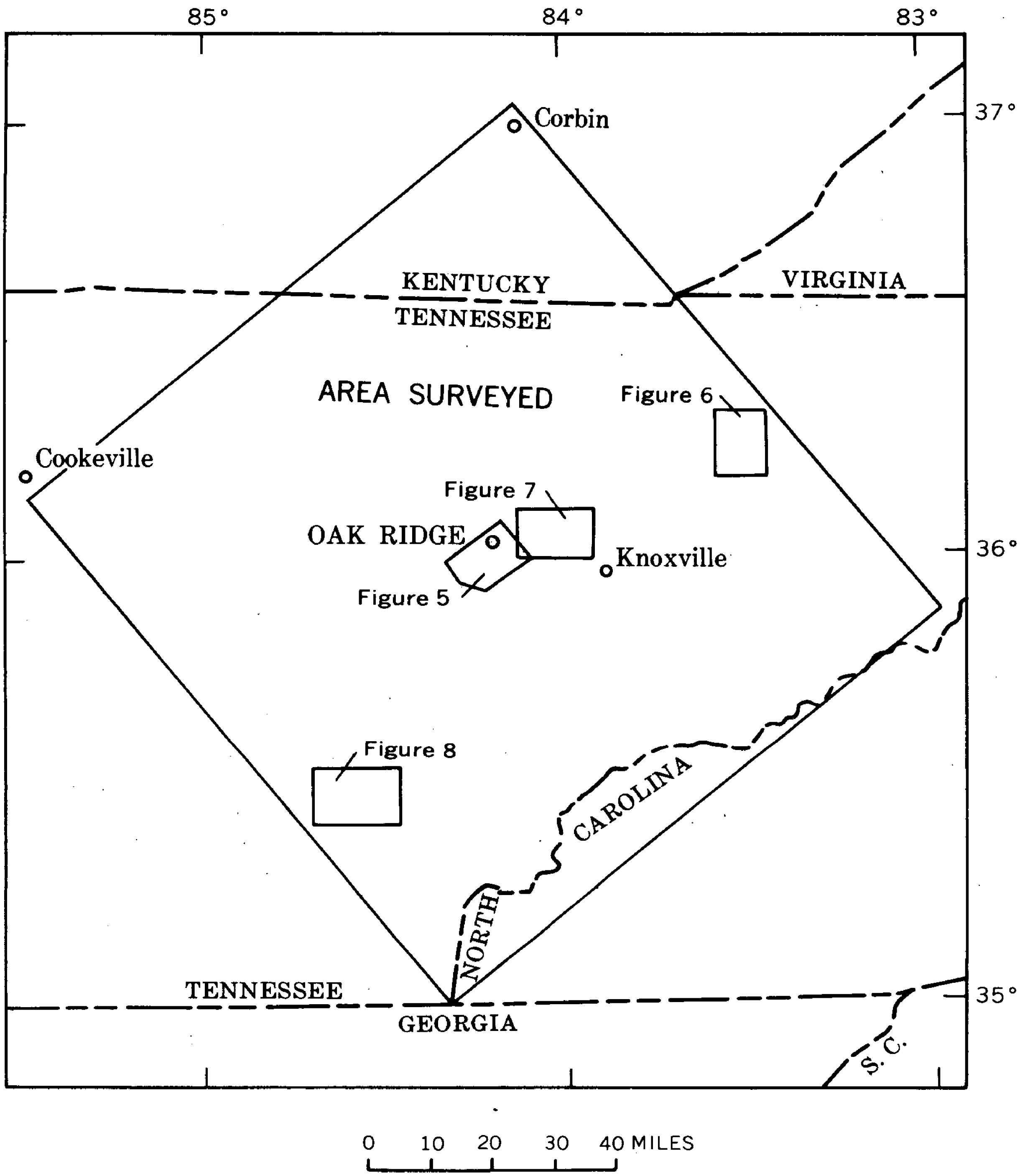


Fig. 1—Location of Oak Ridge National Laboratory Area, Tennessee and Kentucky.

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 edge-mark 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 compensated data have had this nine-tenths of the cosmic component removed. The cosmic background during the survey of the ORNL area ranged from 300 to 430 cps (counts per second) and averaged about 350 cps.

The topography in most of the Oak Ridge survey area was such that the area could be flown without exceeding the range of the altitude-compensating circuit. This was not true of part of the Cumberland Plateau and most of the Great Smoky Mountains within the survey area, and therefore those areas were not flown.

1.3 Scintillation Detection Equipment

The scintillation detection equipment used by the Geological Survey was designed by the Health Physics Division of ORNL and has been described in detail by Davis and Reinhardt [1]. In describing the sensitivity of the equipment, they state (Ref. 1, p. 717): "With a microgram of radium at one foot from the crystals, the counting rate is roughly 2000 cps." Kermit Larsen[2] determined in 1958 that a count rate of about 77,000 cps would be recorded by the Geological Survey equipment 500 ft above an infinite area of fallout that produced a gamma-ray flux of 1 mr/hr 3 ft above the ground.

A block diagram of the equipment is shown in Fig. 2. The detecting element consists of six thallium-activated sodium iodide crystals, 4 in. in diameter and 2 in. thick, and six photomultiplier tubes connected in parallel. The signal from the detecting element is fed through amplification stages to a pulse-height discriminator, which is usually set to accept only pulses from gamma radiation with incident energies greater than 50 kev. The signal is then fed to two rate meters. One rate meter feeds a circuit that records total count on a graphic milliammeter. The signal from the other rate meter is recorded by a circuit from which the cosmic background has been removed. This circuit includes a variable resistance regulated by the radar-altimeter servomechanism which compensates the radioactivity data for deviations from the 500 ft surveying altitude. Tests run to determine the area or cone of response of the detection equipment at an altitude of 500 ft indicate that 85 per cent of the measured gamma radioactivity comes from a circular area on the ground with a radius of 500 ft.

The Valley and Ridge province affords a good example of the value of the altitude-compensation circuit. Flight-line direction was selected at right angles to the geologic and topographic grain. This orientation results in the best definition of geologic units from the aeroradioactivity data. However, the aircraft flying across the

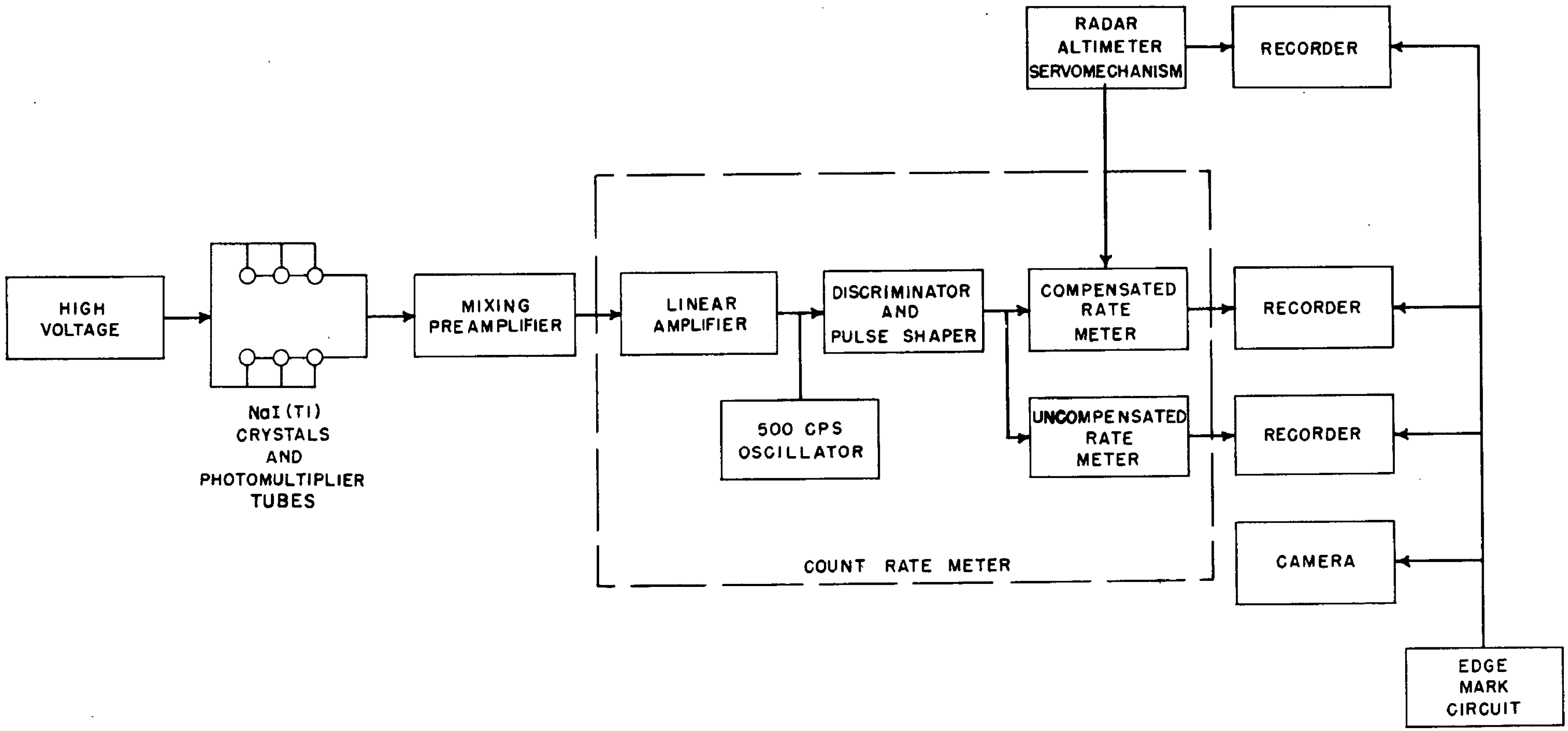


Fig. 2—Diagram of airborne radioactivity survey equipment.

closely spaced valleys and ridges could not always maintain the optimum altitude of 500 ft above the ground. The effect of this is well illustrated by a flight line across Clinch Mountain, northeast of Knoxville (Fig. 3). As the aircraft crossed Clinch Mountain, it was approximately 200 ft below the normal surveying altitude of 500 ft (profile C). The uncompensated radioactivity profile (profile A) shows a sharp peak of approximately 1000 cps over the Clinch Sandstone exposed on Clinch Mountain. The Clinch Sandstone has one of the lowest radioactivity levels of any formation in the survey area, 300 to 400 cps, and this is accurately shown on the compensated radioactivity profile (profile B). Other less striking examples of the value of the altitude-compensation circuit are also shown.

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 (profile B, Fig. 3). 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 minor 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, Corps of Engineers 1:250,000 topographic map series. The final map thus produced (Natural Gamma Aeroradioactivity of the Oak Ridge National Laboratory Area, Tennessee and Kentucky, in pocket) 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 Survey[3].

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.

Sakakura[4] 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

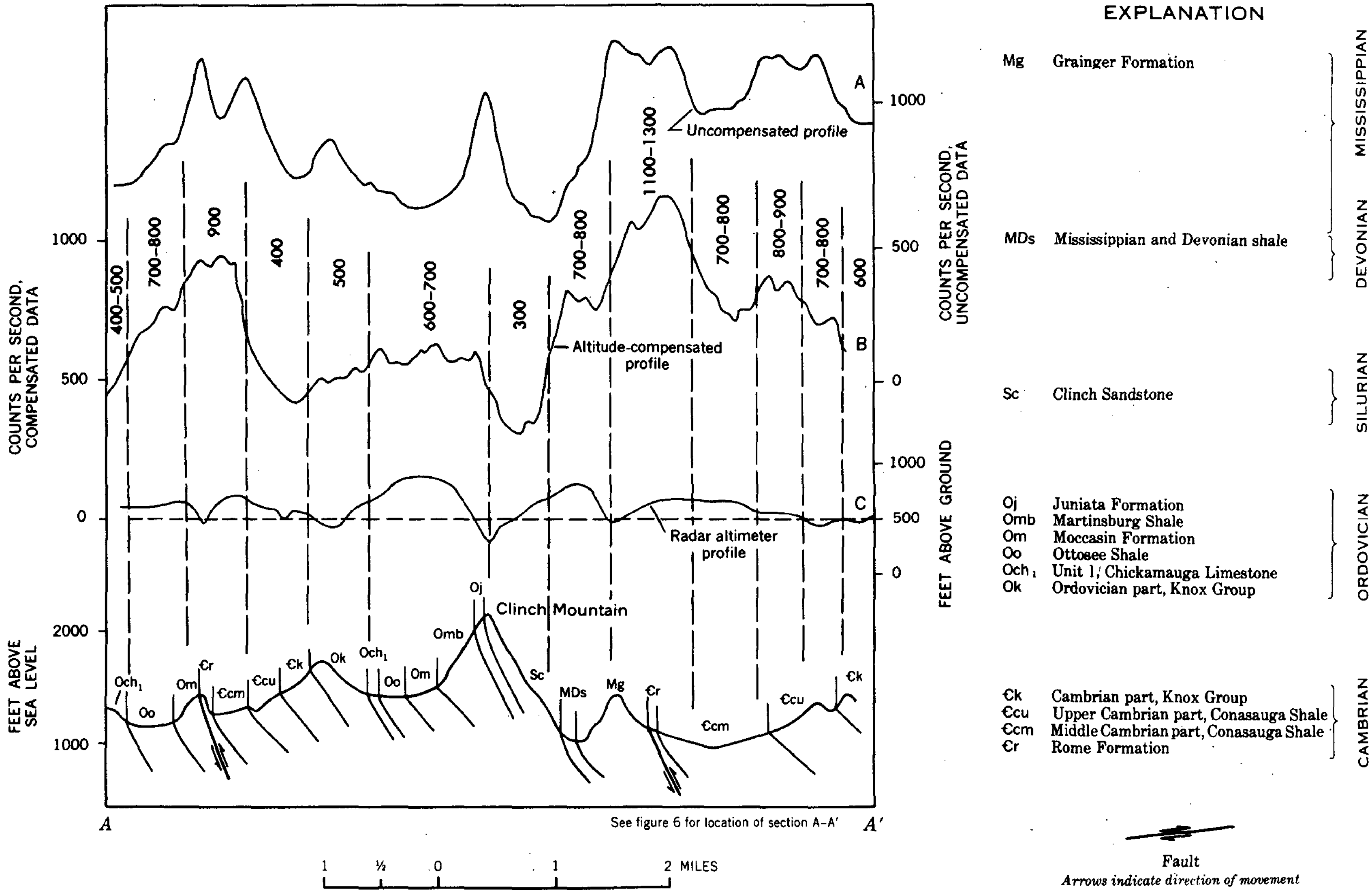


Fig. 3—Profiles showing the effect of geology, topography, and altitude on aeroradioactivity data.

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 Oak Ridge 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 parts of the area due to naturally occurring radionuclides and any fallout present was only 200 cps.

2. GEOLOGY

2.1 General

Four physiographic provinces are present within the survey area. They are, from west to east, the Interior Low Plateaus, the Appalachian Plateaus, the Valley and Ridge province, and the Blue Ridge province. In eastern Tennessee the Appalachian Plateau is called the Cumberland Plateau, the Blue Ridge province is represented by the Great Smoky Mountains, and the portion of the Interior Low Plateaus within the survey is called the eastern Highland Rim (Fig. 4).

Rocks in the Oak Ridge survey area range in age from Precambrian to Pennsylvanian. The oldest rocks, Precambrian to Lower Cambrian clastic rocks with some carbonate rocks, are exposed in the Great Smoky Mountains along the southeast side of the survey area. There deep-seated thrusting has moved these rocks to the northwest over lower Paleozoic sediments. Faulted and folded Paleozoic carbonate and clastic rocks with a pronounced northeast to southwest linearity are exposed across the Valley and Ridge province. The youngest rocks in the area, nearly flat-lying Pennsylvanian clastic rocks, form the Cumberland Plateau.

Formation boundaries, correlation of formations, and geologic ages of the various rock units in eastern Tennessee have been the subject of much controversy. For this report lithologic units and their structural relations throughout the survey area are the most important factors. The geology shown in Fig. 4 and Tables 1 and 2 is therefore adapted from Rodgers[5] since his lithologic units are valid for Tennessee east of the Cumberland Plateau. More recent work in local areas of eastern Tennessee show changes in formation boundaries, but these changes have not been extended regionally. The geologic ages shown on Fig. 4 and Table 2 have been modified from Rodgers to agree with current Geological Survey usage.

Geologic information on the Cumberland Plateau is taken from Wilson and others[6], King[7,8], and Rodgers[5]. Information on the Highland Rim is from Weller and others[9], and Bassler[10].

A description of the geologic units within the survey area and data on the radioactivity level of the units are given in Table 1, and the distribution of these geologic units is shown in Fig. 4. Geologic sections showing changes in the geology across the Valley and Ridge province are shown on Table 2.

Table 1. Radioactivity Level and Generalized Description of Geologic Formations in the Oak Ridge National Laboratory Area

Formation	Radioactivity level, counts per second 1/	Description	Thickness, feet	Remarks
Pennsylvanian rocks, undiv.	400 200-1000	Alternating sandstone and coal-bearing shale units, some conglomerate beds	Up to 4000	
Mississippian rocks, undifferentiated	500 400-700	Predominately limestone, in part argillaceous and in part siliceous, some shale, minor sandstone	Approx. 1000	These data pertain to rocks of the Highland Rim section in the western part of the survey area.
Pennington Formation	500	Shale with thin limestone and sandstone beds	150-400	The Pennington Formation and the Newman Limestone cannot be separated on the basis of radioactivity. This is probably due to three factors: similar lithologies, the relative thickness of the Pennington, and exposure within the survey area on the sides of steep ridges where it is difficult to obtain accurate radioactivity data.
Newman Limestone	500 500-550	Limestone interbedded with calcareous shale and a few thin sandstone beds	600-1500	See Pennington Formation.
Fort Payne Chert	550 500-600	Limestone, siliceous, with nodular chert beds, some pure limestone beds	100-200	The Fort Payne Chert is equivalent in age to the Grainger Formation, the Fort Payne Chert being recognized along the west side of the Valley of Tennessee and the Grainger Formation along the east side of the valley, except that along the Cumberland Escarpment northeast of Speedwell the two formations are laterally gradational into each other.
Grainger Formation	700 650-750	Shale, siltstone, and silty thin-bedded sandstone	400-1100	See Fort Payne Chert.
Chattanooga Shale	550 500-1000	Shale, black, bituminous, slightly uraniferous	10-400	The poor expression of the unit on the radioactivity data is due to the thinness of the unit, except near Cumberland Gap, and its exposure on the sides of steep ridges.

Basal Mississippian and Devonian shale	700 650-750	Shale, black, bituminous, wedge of gray silty shale in middle	400-900	
Hancock Limestone	400	Limestone and dolomite, with many sandy and cherty beds	Up to 300	The radioactivity data is of doubtful reliability due to limited outcrop within the survey area.
Rockwood Formation	550 500-700	Shale, with thin layers of siltstone and limestone and scattered calcareous hematite beds	250-800	Contemporaneous with, and gradational to the southeast into the Clinch Sandstone.
Clinch Sandstone	400 350-800	Sandstone, massive, with some interbedded sandy shale	500	See Rockwood Formation.
Silurian sandstone and shale, undiv.	650 500-800	Massive sandstone overlain by shale which contains thin siltstone and limestone layers	700	Equivalent in age to the Rockwood Formation and the Clinch Sandstone. Very limited within survey area.
Sequatchie Formation	600 500-800	Shale and argillaceous limestone	200-300	Grades eastward into, and is the age equivalent of the Juniata Formation.
Juniata Formation	400 350-500	Shale, siltstone, and silty sandstone	400	See Sequatchie Formation.
Reedsville Shale	650 500-800	Calcareous shale with interbedded limestone, siltstone, and silty shale	250-400	See Martinsburg Shale.
Chickamauga Limestone	650 400-850	Limestone, massive to well-bedded, with some silty or cherty beds, minor shale beds	1300-2200	
Martinsburg Shale	750 700-900	Calcareous shale with interbedded limestone, calcareous siltstone, silty shale, and calcareous sandstone	700-1000	Grades westward into, and is the age equivalent of the Reedsville Shale and unit 4 of the Chickamauga Limestone.
Moccasin Formation	750 700-900	Calcareous shale, siltstone, and silty limestone with some non-silty limestone	800-1000	Grades westward into unit 3 of the Chickamauga Limestone and eastward into the Bays Formation.

Table 1. (Cont'd)

Formation	Radioactivity level, counts per second 1/	Description	Thickness, feet	Remarks
Bays Formation	700 600-750	Shale, siltstone, and sandstone; some limestone	700-1000	See Moccasin Formation.
Sevier Shale	650 550-700	Shale, calcareous, silty to sandy, shaly nodular limestone, carbonaceous shale, sandstone	2500-7000	Age equivalent of the Ottosee Shale, Holston Formation, Lenoir Limestone, and Athens Shale (Ref. 5, p. 78).
Ottosee Shale	700 400-850	Shale, calcareous, and shaly siltstone; some lenses of crystalline limestone, some limy sandstone and quartz-bearing lime-sandstone	1000	Grades westward into, and is the age equivalent of unit 2 of Chickamauga Limestone.
Holston Formation	600 400-750	Limestone, in part fossiliferous; lime-sand, in part quartz-bearing; some shaly limestone and limy shale	200-500	Grades westward into and is the age equivalent of the upper portion of unit 1 of the Chickamauga Limestone.
Lenoir Limestone	650 550-750	Limestone, argillaceous, locally basal pure aphanitic limestone	500-700	Grades westward into the basal portion of unit 1 of the Chickamauga Limestone and eastward into the Athens Shale.
Athens Shale	600 500-700	Shale, calcareous, and shaly nodular limestone	500-700	See Lenoir Limestone.
Knox Dolomite	550 350-850	Dolomite with much chert. Along the northwest side of the Valley of Tennessee the formation is mainly dolomite with minor limestone. Limestone increases and becomes dominant to the southeast across the valley	2500-3000	This unit is called the Knox Group where subdivided into formations: they are from top to bottom, Mascot Dolomite, Kingsport Formation, Longview Dolomite, Chapultepec Dolomite, and Copper Ridge Dolomite.
Newala Formation	600 400-750	Dolomite, massive to well-bedded, aphanitic to fine-grained, some limestone and sandy beds	600-1000	The Newala is equivalent in age to the Mascot Dolomite and the Kingsport Formation and is used in those areas where the two formations have not been separated. See Knox Dolomite.

Mascot Dolomite	550 400-700	Dolomite, well-bedded, grading southward into massive limestone, some sandy beds	400-800	See Knox Dolomite.
Kingsport Formation	550 450-650	Dolomite, massive, fine-grained, some limestone	200	Do.
Longview Dolomite	550 400-700	Dolomite, siliceous, well-bedded, interbedded with aphanitic limestone in upper half of formation	250	Do.
Chepultepec Dolomite	500 400-700	Dolomite, well-bedded, silty, cherty, with a basal sandy member	700-750	Do.
Copper Ridge Dolomite	550 400-800	Dolomite, cherty, asphaltic in part, some dolomitic sandstone in upper portion, limestone prominent in southeastern phase	900-1100	Do.
Conasauga Shale	700 450-1000	Shale, silty in part, some silty limestone beds; upper unit of limestone and dolomite	Approx. 2000	This unit is called the Conasauga Group where subdivided into formations: they are, from top to bottom, Maynardville Limestone, Nolichucky Shale, Maryville Limestone, Rogersville Shale, Rutledge Limestone, and Pumpkin Valley Shale.
Maynardville Limestone	900 550-950	Limestone, massive, forms lower half of formation; thin-bedded dolomite with minor limestone forms upper half	150-300	See Conasauga Shale.
Nolichucky Shale	900 550-1050	Shale, silty, some siltstone, silty limestone lenses near middle of formation	400-750	Do.
Maryville Limestone	900 700-950	Limestone, massive, silty, basal dolomite unit	250-650	Do.
Rogersville Shale	900 800-1100	Shale, silty in part, massive limestone unit near top of formation	0-250	Formation thins to the southeast. Formation disappears and the Maryville and Rutledge Limestone merge outside of survey area.

Table 1. (Cont'd)

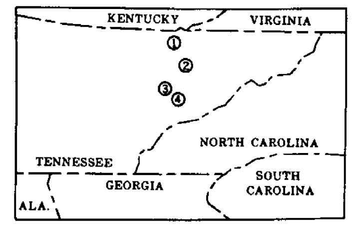
Formation	Radioactivity level, counts per second 1/	Description	Thickness, feet	Remarks
Rutledge Limestone	900 750-1050	Limestone massive, silty in part, upper dolomite unit	100-500	See Conasauga Shale.
Pumpkin Valley Shale	950 750-1200	Shale, silty, thin siltstone beds	200-400	See Conasauga Shale.
Rome Formation	800 500-1200	Sandstone, siltstone, shale, dolomite, and limestone; along northwest side of valley shale and siltstone predominate with some sandstone. Dolomite increases to the southeast and sandstone decreases	Approx. 1200	
Shady Dolomite	650 550-800	Dolomite, locally silty, some limestone in lower part, cherty in upper part	Approx. 800	
Hesse Sandstone	650 550-800	Sandstone, well cemented, interbedded with shale and siltstone	Approx. 500	
Murray Shale	600 550-600	Shale, silty, sandy in part, interbedded with shaly siltstone and fine-grained sandstone	Approx. 300	
Nebo Sandstone	600	Sandstone, well-cemented, interbedded with shale and siltstone	Approx. 500	Radioactivity level based upon one observation.
Nichols Shale	600	Shale, silty, sandy in part, with some thin beds of feldspathic sandstone	800-1000	Radioactivity level based upon one observation.
Cochran Formation	400 400-450	Sandstone and conglomerate, feldspathic, well indurated in upper part of formation; some silty shale and feldspathic siltstone	Approx. 1000	

Sandsuck Formation	900 450-1000	Shale, silty, well-laminated, also sandstone and conglomerate, minor limestone and dolomite	Approx. 4000	
Fine-grained part Ocoee Series	800 550-900	Siltstone and silty shale, sandstone, and conglomerate, minor dolomite and limestone	Approx. 20,000	
Great Smoky Group	750 600-1000	Conglomerate and graywacke sandstone with slate partings between some layers	Approx. 6000	
Lower part, Ocoee Series		Graywacke sandstone, fine-to medium-grained, with much slate	2000	Not flown due to rugged topography, crops out southeast of the survey border.

1/ Single number is average radioactivity level, other indicates general range in radioactivity level

Table 2. Correlation Chart of Geologic Formations Across the Valley and Ridge Province

	Speedwell area (1)	Clinch Mountain (2)	Knoxville area (3)	Chilhowee Mountain area (4)
Pennsylvanian	Pennsylvanian rocks, undif.			
Mississippian	Pennington Formation			
	Newman Limestone			
	Fort Payne Chert	Newman Limestone		
Devonian	Chattanooga Shale	Grainger Formation		
Silurian	Rockwood Formation	Basal Mississippian and Devonian Shale		
Ordovician	Sequatchie Formation			
	Reedsville Shale	Clinch Sandstone		
	Chickamauga Limestone unit 4	Juniata Formation		Pennington Formation
		Martinsburg Shale		Newman Limestone
	unit 3	Moccasin Formation	Bays Formation	Grainger Formation
	unit 2	Chickamauga Limestone, units 1 and 2	Ottosee Shale	Chattanooga Shale
	unit 1		Holston Formation	Bays Formation
	Mascot Dolomite (Knox Group)	Mascot Dolomite	Lenoir Limestone	Ottosee Shale (Sevier Shale)
	Kingsport Formation (Knox Group)	Kingsport Formation	Newala Formation	Holston Formation (Sevier Shale)
	Longview Dolomite (Knox Group)	Longview Dolomite	Longview Dolomite	Athens Shale (Sevier Shale)
	Chepultepec Dolomite (Knox Group)	Chepultepec Dolomite	Chepultepec Dolomite	Knox Dolomite
Cambrian	Copper Ridge Dolomite (Knox Group)	Copper Ridge Dolomite	Copper Ridge Dolomite	
		Upper Cambrian part of Conasauga Shale	Maynardville Limestone	Upper Cambrian part of Conasauga Shale
			Nolichucky Shale	
		Maryville Limestone	Maryville Limestone (undiv.)	Middle Cambrian part of Conasauga Shale
		Rogersville Shale	Rogersville Shale (undiv.)	
		Rutledge Limestone	Rutledge Limestone (undiv.)	Rome Formation
		Pumpkin Valley Shale	Pumpkin Valley Shale (undiv.)	Shady Dolomite
		Rome Formation	Rome Formation	Hesse Sandstone
Cambrian(?)				Murray Shale (Chilhowee Group)
				Nebo Sandstone (Chilhowee Group)
				Nichols Shale (Chilhowee Group)
				Cochran Formation (Chilhowee Group)
Precambrian				Sandsuck Formation (Ocoee Series)
				Fine-grained part of Ocoee Series (Ocoee Series)



Index map to areas shown in correlation chart

Correlations adapted from Rodgers[5]. Geologic ages modified from Rodgers to conform to current U. S. Geological Survey usage.

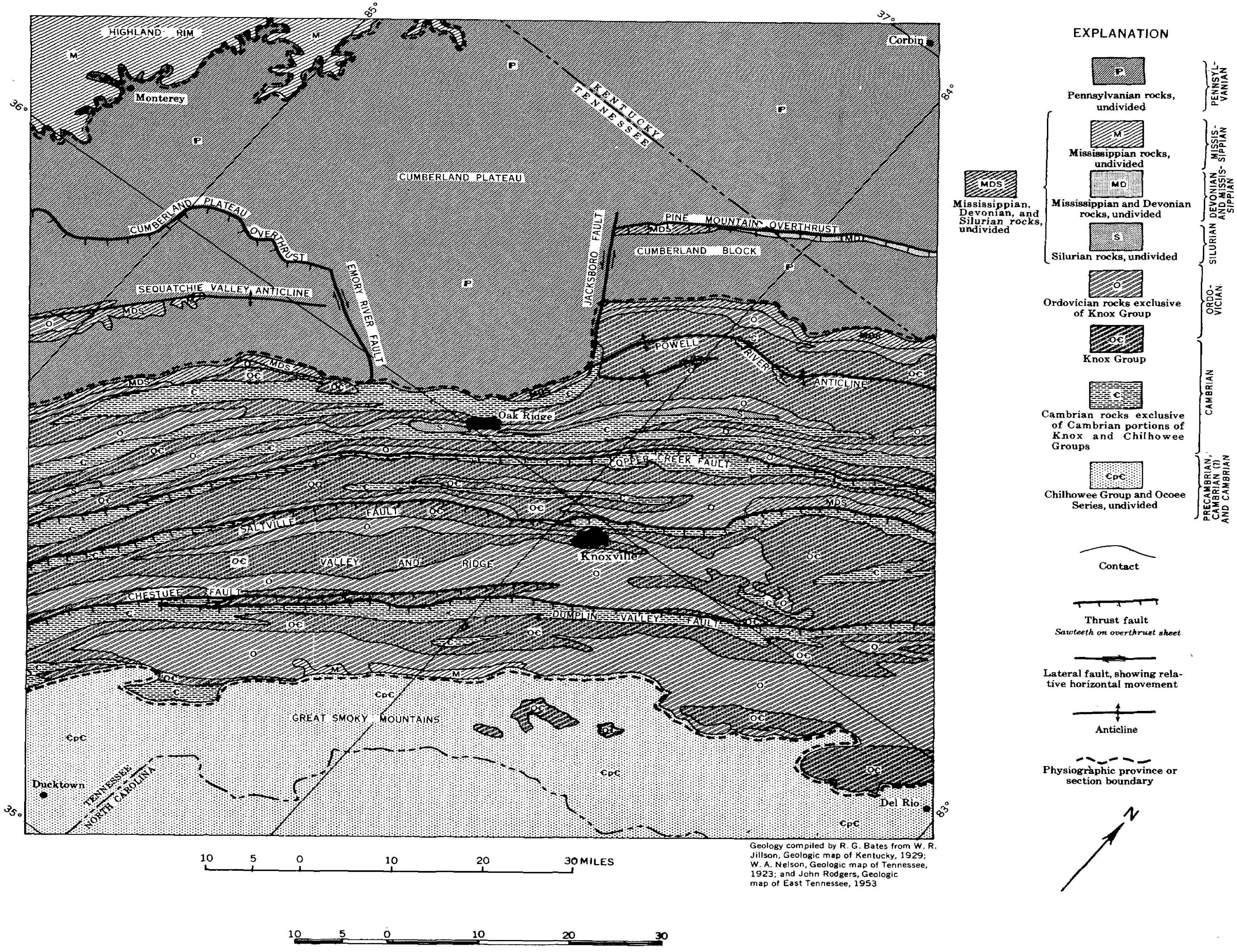


Fig. 4—Generalized geologic map of the Oak Ridge National Laboratory Area, Tennessee and Kentucky.

2.2 Stratigraphy

The Mississippian rocks that form the surface of the eastern Highland Rim are predominantly limestone with lesser amounts of shale and minor sandstone. The resistant siliceous Fort Payne Chert forms the western edge of the eastern Highland Rim west of the survey area. Successively younger rocks crop out to the east: the St. Louis Limestone is exposed over most of the eastern Highland Rim within the survey area. The purity and high solubility of this formation results in the development of many underground streams, caves, and sinkholes. Still younger Mississippian rocks are exposed in the escarpment which forms the western edge of the Cumberland Plateau and upon high hills of the rim. Some of the high hills of the rim are capped by outliers of Pennsylvanian strata. The Mississippian rocks west of the Cumberland Plateau extend under the plateau and reappear on the east side.

The youngest rocks within the survey area, Pennsylvanian in age, occur on the Cumberland Plateau. They consist of at least 4000 ft of a nearly flat-lying sequence of quartzose and feldspathic sandstones, conglomeratic in part, shales, and coal beds. The thicker, more massive sandstones, where they have been breached by erosion, form prominent cliffs. Mississippian, Devonian, and Silurian rocks are exposed along the eastern escarpment of the plateau from Cumberland Gap southwest to Caryville, near Lake City, and from Harriman southwest to the edge of the map. Mississippian and Devonian strata are exposed for 120 miles along the Pine Mountain fault from near its junction with the Jacksboro fault northwestward into Virginia. At the southwestern end of the fault in Elk Valley Silurian and Upper Ordovician rocks are also exposed[11]. Erosion of the Sequatchie Valley anticline has exposed rocks of the Knox Group of Cambrian and Ordovician age. Mississippian rocks are also exposed in the more deeply entrenched river valleys of the western part of the plateau.

The oldest rocks exposed in the Valley and Ridge province are the shales of the Rome Formation that have been brought to the surface by a complex series of subparallel low-angle thrust faults. Although the Middle Cambrian through Lower Ordovician strata contain shale and sandstone, they are predominantly carbonate rocks; dolomite with lesser amounts of limestone. Carbonate rocks continue to be the dominant rock type through Middle Ordovician time along the northwest flank of the province. The remainder of the Paleozoic sedimentary rocks are mostly shale with some sandstone and limestone beds. Carbonate rocks predominate in the Mississippian strata along the northwest side of the valley; however, they grade to the southeast into shale, silty sandstone, and quartz-pebble conglomerate. Pennsylvanian sedimentary beds which at one time were present in at least the western portion of the valley, now have been almost completely removed by erosion. The Paleozoic sequence within the valley has a thickness of more than 6 miles.

A small peridotite body is exposed on the north bank of Norris Reservoir 5 miles northwest of Maynardville. This is the only known intrusive body in the Valley and Ridge province south of Virginia.

Continued thrusting from the southeast caused numerous subparallel northeast to southwest trending low-angle thrust faults, This resulted in repetition and omission of beds, particularly within the Cambrian and Lower Ordovician stratigraphic sequence.

The Great Smoky Mountains within the survey area are composed of clastic rocks of the Ocoee Series and Chilhowee Group and the massive Shady Dolomite. The Ocoee Series of Precambrian age consists of over 20,000 ft of sandy and silty shale, slate, well-indurated sandstone, and conglomerate. The rocks of the Ocoee Series have been metamorphosed and the degree of metamorphism increases to the southeast. Large-scale thrust faulting has taken place in the Ocoee. The Knox Dolomite of Cambrian and Ordovician age is exposed through windows in the overthrust Ocoee. In at least two of the windows, Middle Ordovician limestone and shale are also exposed. The Chilhowee Group of Cambrian and Cambrian(?) age is composed of several thousand feet of micaceous sandy shales and sandstones, which have been preserved in synclines along the northwest edge of the province. The overlying Shady Dolomite of Cambrian age is the youngest formation within the province. It consists of massive dolomite, with nodules and masses of black chert in the uppermost part.

Over the consolidated Precambrian and Paleozoic rocks of eastern Tennessee lies a nearly continuous mantle of unconsolidated material. Most of the mantle consists of residual deposits resulting from weathering of the bedrock in place. Commonly the residual mantle retains enough of the characteristics of the underlying rocks to greatly aid mapping of bedrock. Great aprons of rocky material have formed in the Great Smokies.

Terrace deposits of Pleistocene gravels are found along most of the larger rivers. Especially in the eastern part of the Valley and Ridge province, there are extensive old high-level alluvial deposits, not generally recognized as such[12]. These deposits may be several miles from the rivers and a few hundred feet above present stream level. Alluvial deposits are found along all the streams and rivers, their extent varying with the size of the river.

2.3 Structure

The Interior Low Plateaus province is present only in the western corner of the survey area where it is represented by the eastern portion of the Highland Rim section. A karst topography has developed on the nearly flat-lying Mississippian limestone that forms the surface rocks of the eastern Highland Rim. Mississippian rocks also crop out to the east in the escarpment along the western side of the Cumberland Plateau. Outliers of Pennsylvanian strata are present on some of the higher hills, indicating a former greater western extent of the Cumberland Plateau.

The Cumberland Plateau is a broad upland of nearly flat-lying Pennsylvanian strata. Streams and rivers cut deeply into these rocks, and the intervening ridges have accordant crests.

The strata have been warped into a series of anticlines and synclines, but in most places the deformation was so slight that over large areas the strata appear to be nearly flat. Throughout most of the Plateau the strata dip to the southeast a few tens of feet per mile. Along the escarpment forming the eastern edge of the plateau the beds are generally vertical or dip steeply northwest. However, at several localities along the escarpment between Rockwood and Spring City the Pennsylvanian strata dip to the southeast beneath the strata of the Valley and Ridge province and are exposed in several fensters east of the escarpment (Ref. 6, p. 17, ref. 13, p. 16-19).

Two prominent thrust faults with displacements of as much as 10 miles are present on the Plateau. They are the Cumberland Plateau overthrust, which is bounded on the northeast by right lateral fault, the Emory River fault, and the Pine Mountain thrust fault, which is bounded on the southwest by the Jacksboro fault, a left lateral fault. Pennsylvanian strata in the Pine Mountain overthrust or Cumberland block were moved approximately 10 miles northwest and were raised 500 ft relative to Pennsylvanian strata south of the Jacksboro fault (Ref. 6, p. 16).

The Sequatchie Valley anticline is parallel to Valley and Ridge structure and can be traced for 200 miles from the Emory River fault southwestward into Alabama. The anticline has been eroded, and Cambrian and Ordovician strata are exposed along its axis.

The Valley and Ridge province consists of parallel slightly arcuate valleys and ridges with a northeast to southwest trend. These structures have formed as the result of strong compressive forces from the southeast which caused deformation by thrusting, folding, or both. Most of the structures northwest of the Saltville fault are the result of thrust faulting, whereas those southeast of the fault resulted from folding although some thrust faults are present. Most of the folds are asymmetrical with steeply dipping or overturned northwest limbs and gently dipping southeast limbs.

Most of the thrust faults bring shaly rocks of the Rome or Conasauga Formations to the surface. The thrusting and probably the folding are confined to the sedimentary rocks above the Precambrian basement (Ref. 8, p. 46). Some of the great thrusts, such as the Saltville and Copper Creek faults, can be traced for more than 100 miles along strike.

The Blue Ridge province in eastern Tennessee and western North Carolina is a massive highland area 75 miles wide. Topographically the area is very rugged, and relief between ridge top and valley bottom exceeds a mile in many places. Within the survey area the rocks consist almost entirely of the Ocoee Series. The Chilhowee Group is present only in the remnants of three synclines along the western edge of the province.

In contrast to the Valley and Ridge province where folds formed mainly by flexing, folds in the Blue Ridge formed mainly by shear with the extensive development of slaty cleavage. The stratified overburden and the basement rocks deformed as a unit.

Deformation of this kind resulted in folds in some places and low-angle thrusts in others. These thrusts differ from those in the Valley and Ridge province in that they extend deep into the basement (Ref. 8, p. 47). In Sevier County several subparallel high-angle thrust faults are present. To the southeast these faults bring increasingly older rocks to the surface, and the grade of metamorphism rises. The overridden younger rocks are exposed in several windows in the thrust sheets.

The deformation of the Paleozoic rocks and probably most of the deformation of the Precambrian rocks in the Oak Ridge area reached their culmination in Premian time (Ref. 5, p. 126).

3. DISTRIBUTION OF AERORADIOACTIVITY

3.1 ORNL Survey Area

The natural gamma radioactivity level within the ORNL survey area ranged from 200 to 1400 cps. Owing to a lack of control information, it was necessary to assume that fallout, if present, was uniform throughout the survey area. The general level of radioactivity on the Cumberland Plateau, as low as 300 to 500 cps over large parts of the plateau, indicates that fallout, if present, is a minor factor in the total radioactivity level.

The highest radioactivity level measured occurred in the Valley and Ridge province, although the average radioactivity level of the Great Smoky Mountains is the highest of the four provinces within the survey area. All provinces show a considerable range in radioactivity: the Great Smoky Mountains, 500 to 1200 cps; the Valley and Ridge province, 300 to 1400 cps; the Cumberland Plateau, 200 to 1000 cps; and the Highland Rim, 300 to 700 cps.

The radioactivity units in the Valley and Ridge province exhibit strong linearity. The units have a general northeast to southwest trend and are parallel to the regional strike. Some units can be traced from one side of the survey area to the other, a distance of 100 miles.

There is some indication that radioactivity units within the Great Smoky Mountains tend to roughly parallel those in the Valley and Ridge province. However, not enough of the mountains were surveyed to state this with certainty.

A linear radioactivity low unit is located along Pine Mountain on the Cumberland Plateau. Linear radioactivity units are also present in the vicinity of Middlesboro, Ky. Elsewhere on the plateau there is no apparent pattern in the radioactivity units. Likewise, no pattern was noted in the radioactivity units over the Highland Rim in the extreme western part of the survey area.

3.2 ORNL Reservation

The distribution of natural and facility-induced gamma radioactivity within the ORNL reservation is shown in Fig. 5. It should be noted that some radioactivity readings shown on the map of the reservation are higher than the range of values observed from geologic sources elsewhere within the ORNL area. These higher readings result from normal atomic energy operations at the ORNL facility. Also, the Geological Survey equipment is extremely sensitive to small changes in radioactivity levels.

Information on radioactivity levels in the environs and outside the plant boundaries of AEC and contractor installations are reported in special periodic reports from each installation. Quarterly reports entitled, Environmental Levels of Radioactivity for the Oak Ridge Area, are made available directly to the public by the AEC, and summaries are also published in the U. S. Public Health Service series titled "RADIOLOGICAL HEALTH DATA", issued monthly and available from the Government Printing Office, Washington, D. C.

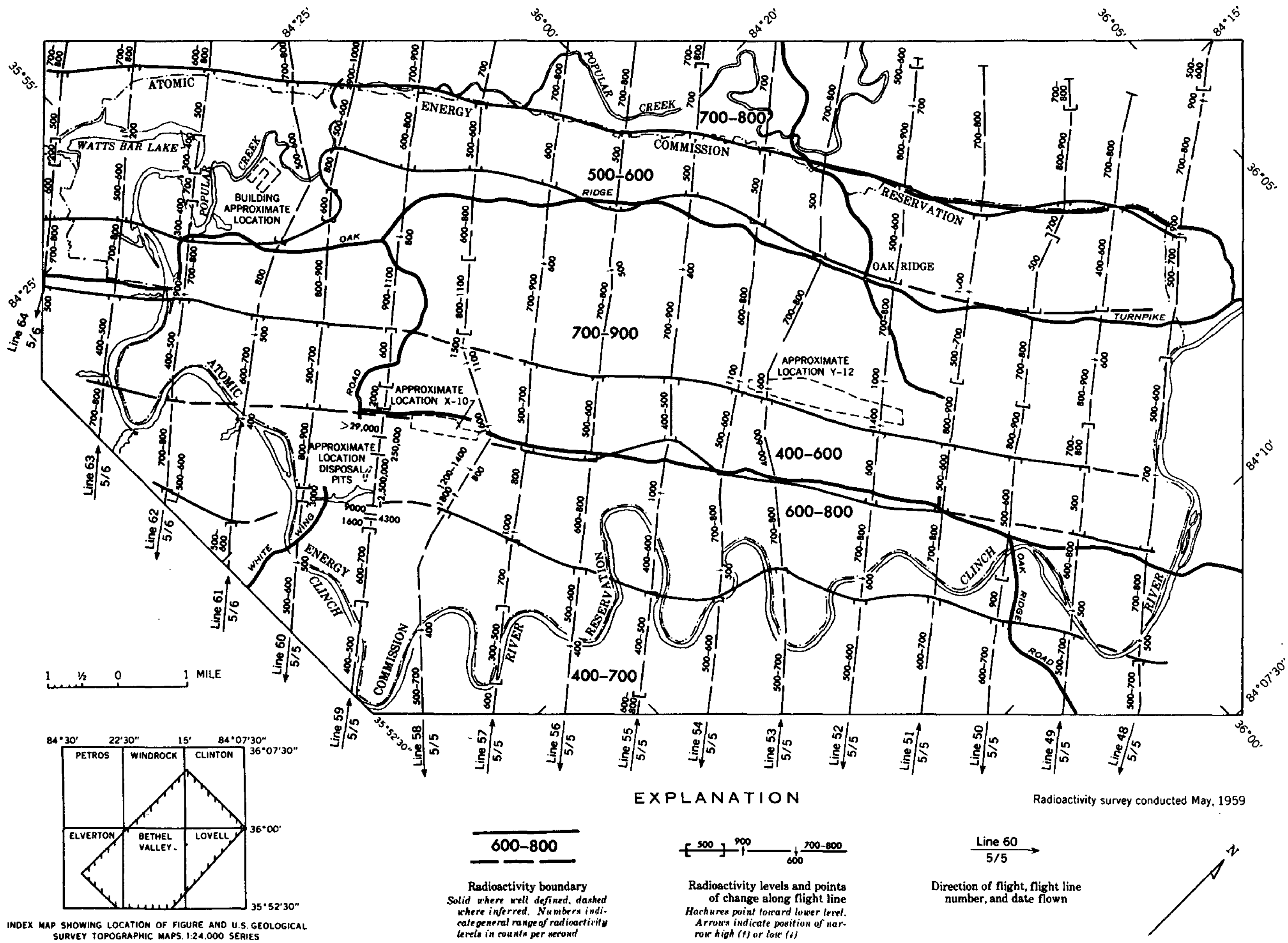


Fig. 5—Airborne radioactivity survey, Oak Ridge National Laboratory reservation, Tennessee.

4. RELATION OF AERORADIOACTIVITY DATA TO AREAL GEOLOGY

4.1 Highland Rim

Rocks of the Highland Rim province occur only in the extreme western and northwestern part of the survey area. No radioactivity pattern was noted, probably because only one formation, the St. Louis Limestone, is exposed over most of the area. Younger Mississippian rocks are exposed in the western escarpment of the Cumberland Plateau where the topography is such that it is difficult to get meaningful radioactivity data.

4.2 Cumberland Plateau

Over most of the Cumberland Plateau there is no strong pattern to the aeroradioactivity data. In general, the radioactivity level increases from southwest to northeast and decreases from southeast to northwest (map in pocket). This is probably a reflection of the increase in the shale to sandstone and conglomerate ratio toward the northeast and southeast, since the older Pennsylvanian rocks have proportionately more sandstone and conglomerate than the younger Pennsylvanian rocks. A well-defined radioactivity low of 300 to 600 cps extends along Pine Mountain and the Pine Mountain fault from the edge of the unsurveyed area just east of the town of Elk Valley to the northeastern boundary of the survey area, a distance of 30 miles. Most of the strata within this unit are of Early Pennsylvanian age and have the same radioactivity level here as they do over more extensive exposures to the northwest and southwest. Also within this radioactivity unit a narrow band of Lower Mississippian, Upper Devonian, and Silurian rocks has been thrust over Pennsylvanian rocks along the Pine Mountain fault. As determined elsewhere in the survey area, these rocks have a higher radioactivity level than the surrounding Pennsylvanian rocks. Therefore their lack of expression in the radioactivity data is probably due to their narrow outcrop width.

The Cumberland overthrust block is part of the Cumberland Plateau. It is bounded on the southeast by Cumberland Mountain, on the northwest by the Pine Mountain fault, and on the southwest by the Jacksboro fault. Linear radioactivity units are present over this block in the vicinity of Middlesboro, Ky. These units have a northeast to southwest trend and include some units that have the highest radioactivity level noted over the rocks of the Cumberland Plateau. The units die out to the southwest, and their extent to the northeast from the survey boundary is unknown. The reason for their localization at this point is not known.

4.3 Valley and Ridge Province

The aeroradioactivity units within the Valley and Ridge province closely parallel the regional strike (Fig. 4 and map in pocket). Some units are continuous across the survey area, a distance of 100 miles, and many can be traced for 50 miles or more.

There is remarkably good correlation between radioactivity units and geology within the Valley and Ridge province. This is particularly noteworthy considering the relatively low levels of radioactivity involved and considering that although some adjacent radioactivity units differ by only 100 cps, this difference is geologically significant. The area is also geologically complex; repeated thrust faulting has resulted in repetition and omission of beds, and units are laterally gradational within the area (Table 2).

The large number of radioactivity units and the relative complexity of the geology preclude at this time a detailed discussion of the relation noted between the two. Therefore three areas selected as being representative of the province are discussed in detail.

Fig. 6 is a radioactivity and geologic map of the Clinch Mountain area, 30 miles northeast of Knoxville. In the northern part of this area, some of the radioactivity units are disrupted by the waters of Norris Reservoir. Away from the reservoir the units parallel the strike direction; therefore, where the units are broken by the reservoir, they have been projected along strike. This is indicated by dashed lines on the map.

The Clinch Sandstone and Juniata Formation have the lowest radioactivity levels of all the formations within the province. On Clinch Mountain the Clinch Sandstone and Juniata Formation are outlined by a 300- to 400-cps units. In the northwest corner of the map, these same formations plus the Rockwood Formation lie within a 400-cps low. The Rockwood Formation, where best exposed along the northwest side of the province, is predominantly shale and has a slightly higher radioactivity level. However, the Rockwood Formation becomes increasingly sandy to the southeast and merges with the Clinch Sandstone somewhere between the Hunter Valley fault and Clinch Mountain. Therefore, the Rockwood Formation just north of the Hunter Valley fault included with the Clinch Sandstone and the Juniata Formation in the 400-cps radioactivity low is probably quite sandy and has a radioactivity level approaching that of the Clinch Sandstone.

The Rome Formation and the Conasauga Shale have a high radioactivity level and form the most distinctive radioactivity units within the province. In many places, such as around Norris Reservoir and 3 miles north of Clinch Mountain, these formations cannot be separated by the radioactivity data. South of Clinch Mountain three high radioactivity units are associated with these two formations; the highest, 1100 to 1300 cps, is associated with the Rome Formation, the next highest, 900 to 1000 cps, is related to the Upper Cambrian part of the Conasauga Shale, and the lowest, 700 to 900 cps, occurs over the Middle Cambrian part of the Conasauga Shale.

Immediately northwest of Clinch Mountain, the Chickamauga Limestone, units 1 and 2, the Moccasin Formation, and the Martinsburg Shale are enclosed by a 600- to 800-cps radioactivity unit. Three miles northwest these same formations are present with the exception of the Martinsburg Shale, which has been overthrust by the Rome Formation. The Chickamauga Limestone, units 1 and 2, are mostly in the low-level radioactivity unit associated with the Knox Dolomite, and only the Moccasin Formation has a radioactivity level similar

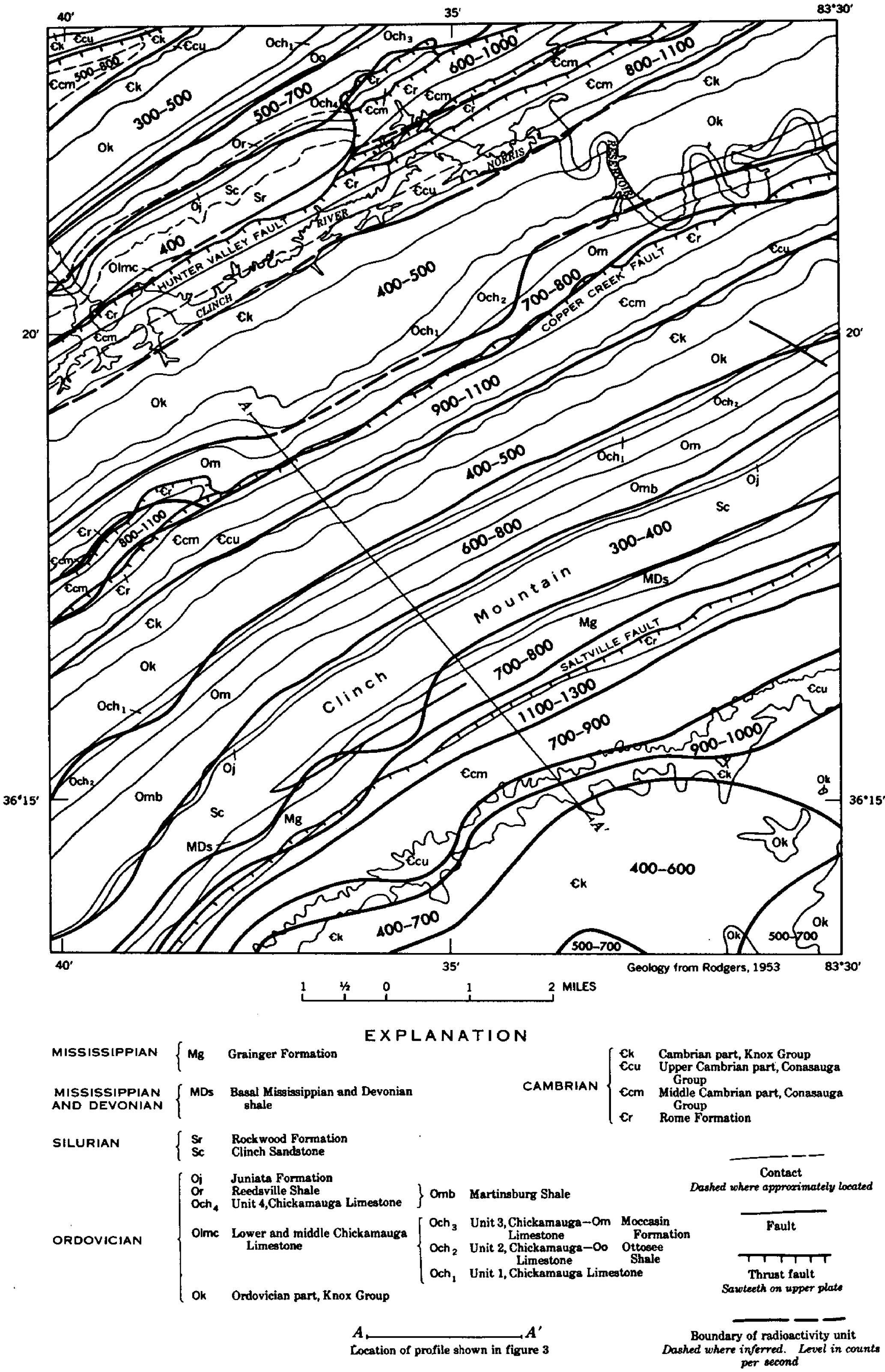


Fig. 6—Relationship of aeroradioactivity units to geology around Clinch Mountain, eastern Tennessee.

to that just north of Clinch Mountain. In the northwest corner of the mapped area these formations are more calcareous. The Moccasin Formation and the Martinsburg Shale have been replaced by units 3 and 4 of the Chickamauga Limestone and the Reedsville Shale (Table 2). Again the Chickamauga Limestone, units 1 and 2, are included in the low radioactivity unit associated with the Knox Dolomite. The upper portion of the sequence, units 3 and 4 of the Chickamauga Limestone and the Reedsville Shale, are outlined by a moderate-level radioactivity unit, as are rocks of equivalent age to the southeast. The increase in radioactivity level of units 1 and 2 of the Chickamauga Limestone toward the southeast is probably a reflection of the increasing shale content in that direction. A few miles south of the mapped area, unit 2 becomes predominantly shale and is called the Ottosee Shale. The Moccasin Formation and the Martinsburg Shale are gradational to the northwest into the more calcareous Chickamauga Limestone, units 3 and 4, and the Reedsville Shale. The radioactivity level remains approximately the same, probably because of the Reedsville Shale and the volcanic ash beds near the top of unit 3 of the Chickamauga Limestone.

The Knox Dolomite exhibits a uniformly low radioactivity level throughout the mapped area. The contact of the Knox Dolomite with the more radioactive underlying Conasauga Shale is usually well defined by the aeroradioactivity data. The contact of the Knox Dolomite with the only slightly more radioactive overlying calcareous formations is less distinct.

The area around Clinton, 15 miles northwest of Knoxville, is shown on Fig. 7. Geologically the area is similar to the area around Clinch Mountain except that the youngest rocks in the Clinton area are Silurian in age and the youngest rocks in the Clinch Mountain area are Mississippian in age.

As in the Clinch Mountain area, the Rome Formation and the Conasauga Shale together form the most distinctive radioactivity units, particularly south of the Copper Creek and Beaver Valley faults. The rock unit immediately south of the Hunter Valley and Whiteoak Mountain faults is mapped as Rome(?) Formation. The radioactivity level of this rock unit, 600 to 700 cps, is lower than the 800- to 1100-cps level of the rock unit immediately south which is mapped as Rome Formation and is the same level as the Conasauga Shale north of the Hunter Valley fault. This difference in radioactivity level indicated that the Rome(?) Formation could be the Conasauga Shale. Recent geologic mapping in this area showed that the Rome(?) Formation is the Conasauga Shale as indicated by the radioactivity data[14].

The low-level radioactivity units associated with the Knox Dolomite show a progressive change from southeast to northwest across the mapped area. South of the Beaver Valley fault, the Mascot Dolomite, the uppermost formation of the Knox Group, is contained within the higher radioactivity unit associated with units 1 and 2 of the overlying Chickamauga Limestone. Between the Beaver Valley and Copper Creek faults, the upper and lower contacts of the Knox Dolomite are very well delineated by a 500- to 700-cps radioactivity unit. North of the Copper Creek fault and also around the town of Clinton, the lower part of the overlying Chickamauga Limestone is included in the radioactivity unit with the Knox Dolomite. This relation was noted in the Clinch Mountain area, and the cause is

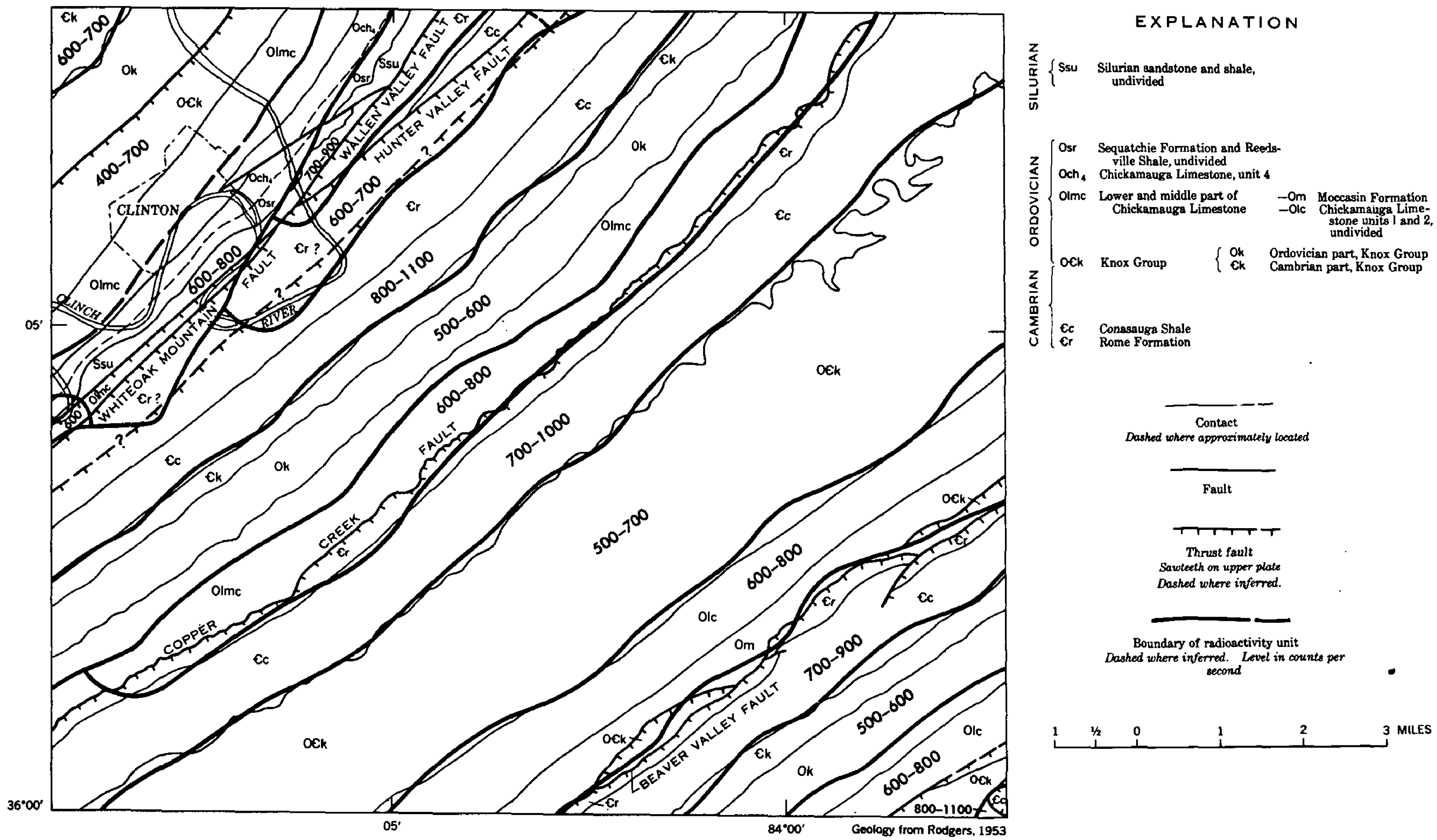


Fig. 7—Relationship of aeroradioactivity units to geology near Clinton, Tennessee.

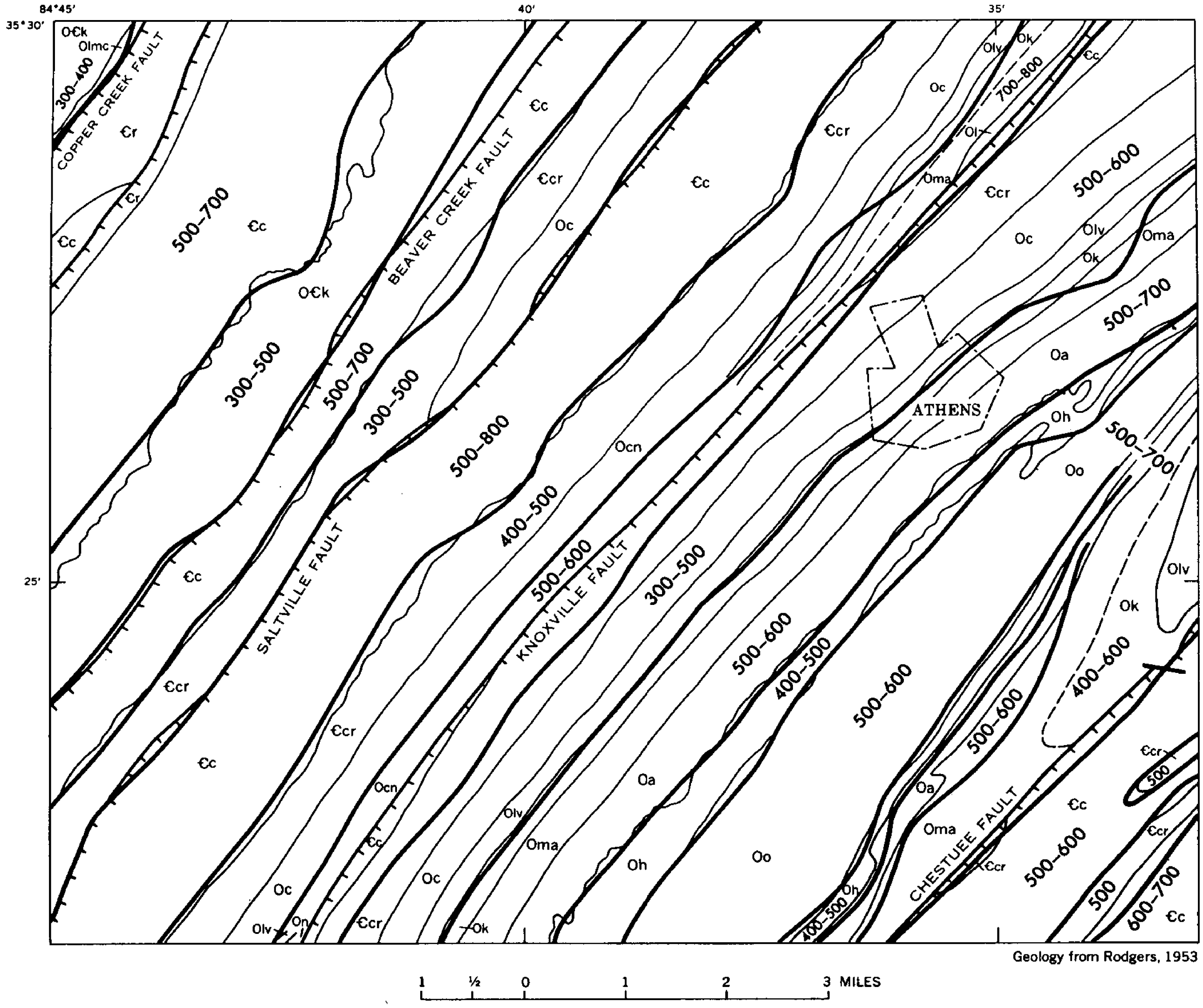
probably the same: a decreasing shale content with resultant decrease in radioactivity level within the Chickamauga Limestone from southeast to northwest.

In the radioactivity unit associated with the Knox Dolomite north of Clinton, Knox Dolomite, undivided, has been thrust over the Ordovician part of the Knox. The Cambrian part of the Knox Dolomite lies within a slightly higher radioactivity unit to the northwest.

East of Clinton the Wallen Valley and Hunter Valley faults join to form the Whiteoak Mountain fault, which passes approximately 1 mile south of Clinton. Other faults are also present. Along this fault system the radioactivity units are not as geologically definitive as elsewhere in the area. Along the Wallen Valley fault, a 700- to 900-cps radioactivity unit includes the Rome Formation overthrust on Silurian sandstone and shale, which overlie the Sequatchie Formation and the Reedsville Shale. If one considers the structural complexity of the area and the flight-line interval of 1 mile, these shaly units are fairly well defined. These same formations plus unit 4 and the upper portion of the lower and middle parts of the Chickamauga Limestone are associated with a 600- to 800-cps radioactivity unit that extends from south of Clinton to beyond the edge of the mapped area northeast of the town. The northern boundary of this unit seems to follow a stratigraphic horizon within the lower and middle parts of the Chickamauga Limestone. The southern boundary, however, beginning east of Clinton crosses formational boundaries from northeast to southwest with apparent disregard for stratigraphy to a point within the Rome Formation south of Clinton. At this point it swings west to the Whiteoak Mountain fault and then southwest to parallel the fault. The change in direction from southwest to west is controlled by data from only one flight line and thus may very well represent only some local geologic feature.

Fig. 8 shows the geology and aeroradioactivity data of the area around Athens, 50 miles southwest of Knoxville. Rocks within the mapped area range in age from Early Cambrian to Middle Ordovician. The change in lower Middle Ordovician rocks from principally carbonate sequence in the northwest to a carbonate and shale sequence in the southeast is well shown in this area.

The definition of the Knox Dolomite or Knox Group by the radioactivity data in the Athens area is particularly noteworthy. North of the Copper Creek fault, the 300- to 400-cps radioactivity unit associated with the Knox Dolomite also includes a narrow band of the lower and middle parts of the Chickamauga Limestone, undivided. This is similar to relations noted in Figs. 6 and 7 to the northeast where, if the lower half of the Chickamauga Limestone is virtually all carbonate, it is included in the radioactivity unit associated with the Knox Dolomite. North of the Beaver Valley fault, the Knox is exposed along a ridge. The northern boundary of the radioactivity unit associated with the Knox at this point is north of the mapped geologic boundary in most places. The contact of the Knox with the Conasauga Shale to the north is located near the top of the steep north side of the ridge. The northward displacement of the radioactivity unit boundary may well reflect movement of weathered Knox Dolomite down the steep slope and over the more radioactive Conasauga Shale. The



EXPLANATION

CAMBRIAN ORDOVICIAN

Olmc	Lower and middle part of Chickamauga Limestone, undivided	Oo / Oh / Ol	Ottosee Shale / Holston Formation / Lenoir Limestone	—Oa	Athens Shale
O€k	Knox Dolomite	Oma / Ok / Olv / Oc / €cr	Mascot Dolomite / Kingsport Formation (On) / Longview Dolomite / Chepultepec Dolomite / Copper Ridge Dolomite	On	Newala Formation } Ocn Ordovician part, Knox Group
€c / €r	Conasauga Shale / Rome Formation				

Contact
Dashed where approximately located

Fault

Thrust fault
Sawteeth on upper plate

Boundary of radioactivity unit
Level in counts per second

Fig. 8—Relationship of aeroradioactivity units to geology near Athens, Tennessee.

southern boundary of the radioactivity unit is the trace of the Beaver Valley fault except for about 3 miles at the north end.

The Copper Ridge Dolomite and the Chepultepec Dolomite of the Knox Group lying between the Beaver Valley and Saltville faults are accurately delineated by a 300- to 500-cps radioactivity low. Southwest of Athens and immediately northwest of the Knoxville fault, exposures of the Knox Group are poor, and the Ordovician part of the group has not been separated into its component formations as it is to the northeast and farther southwest. A 400- to 500-cps radioactivity unit at this point includes the Copper Ridge Dolomite and a portion of the Ordovician part of the Knox. The southwestern and northeastern ends of the southeastern boundary of this radioactivity unit appear to be related to the Chepultepec Dolomite-Longview Dolomite contact, and the unit boundary probably reflects this contact in the area where the poor exposures do not allow separation of the formations by ground mapping. This demonstrates one of the more important geologic uses for airborne radioactivity data in areas of deep weathering and residual soils: the tracing of geologic contacts between scattered outcrops.

A 500- to 600-cps radioactivity unit extends along the Knoxville fault. Northwest of the fault the upper part of the Knox Group is included in the western part of this unit. In the eastern part of this unit, the Lenoir Limestone, in addition to the upper part of the Knox Group, is included. Southeast of the fault the lower part of the Copper Ridge Dolomite and a wedge of the Conasauga Shale are included in the western part of the unit and to the east only part of the Conasauga Shale and none of the Copper Ridge Dolomite is included in the unit.

Immediately south of this unit and including the northern half of the town of Athens, a 300- to 500-cps unit includes all, or part of, the Copper Ridge Dolomite, and the Chepultepec Dolomite, the Longview Dolomite, and, except for the distance of a few miles southwest of Athens, the Kingsport Formation. The overlying Mascot Dolomite, the top formation of the Knox Group, is included with the Athens Shale in a slightly more radioactive unit to the southeast.

Along the Chestuee fault the Conasauga Shale and a small sliver of the Copper Ridge Dolomite have been thrust against the Mascot Dolomite, the Kingsport Formation, and the Longview Dolomite. The boundary between two radioactivity units run along this fault separating the less radioactive (400 to 500 cps) formations of the Knox Group from the more radioactive (500 to 800 cps) Conasauga Shale. Narrow exposures of the Copper Ridge Dolomite in the extreme southeastern corner of the map have no expression in the radioactivity data.

The Rome Formation is present only in the northwest corner of the mapped area. Along the Copper Creek fault, the Rome is thrust against rocks of the lower and middle parts of the Chickamauga Limestone. This is accurately reflected by a radioactivity-unit boundary that traces the fault and separates the less radioactive Chickamauga Limestone and Knox Dolomite from the more radioactive Rome Formation. South of the fault the Rome Formation and the Conasauga Shale cannot be separated by the radioactivity data. Together they are very well outlined by a 500- to 700-cps unit that separates them from the Chickamauga Limestone and Knox Dolomite to the northwest and the Knox Dolomite to the southeast.

South of the Saltville fault, the contact of the Conasauga Shale with the Knox Group to the northwest and southeast is well defined by a 500- to 800-cps radioactivity unit. Along the Chestuee fault the more radioactive Conasauga Shale is thrust against less radioactive rocks of the Knox Group. This is reflected by the radioactivity-unit boundary that follows the fault trace.

South of Athens the Athens Shale, the Holston Formation, and the Ottosee Shale are exposed on the limbs of a doubly-plunging syncline that trends northeast. Toward the south on the southwest limb of the syncline, the Holston Formation is fairly well defined by a 400- to 500-cps radioactivity unit that separates it from the slightly more radioactive Athens Shale to the northwest and the Ottosee Shale to the southeast. Elsewhere the Holston Formation is apparently too narrow to be reflected in the radioactivity data. The Mascot Dolomite and the Athens Shale have the same radioactivity level as the Ottosee Shale. Where the intervening Holston Formation has no expression in the radioactivity data, the four formations are contained in one radioactivity unit with a level of 400 to 700 cps.

4.4 Great Smoky Mountains

The greater part of the Great Smoky Mountains within the Oak Ridge survey area could not be flown owing to rugged topography. The border of the area surveyed is indicated by a dashed line on the large radioactivity map (in pocket).

The mapped geologic units are not well defined by the radioactivity data. An irregular line running from Starr Mountain in the south northeast along Chilhowee Mountain and English Mountain and then east to Stone Mountain is the approximate boundary between the Valley and Ridge province and the Great Smoky Mountains. This boundary can be approximately located by a change in radioactivity level from less than 1000 cps west of this line to more than 1000 cps east of this line. However, a 300- to 500-cps radioactivity unit lies along the southeast flank of Starr Mountain. The southern boundary of this unit separates rocks of the Chilhowee Group forming Starr Mountain from the Sandsuck Formation to the southeast. The northern boundary of the unit does not appear to be related to any one formation within the group and cuts across all formation boundaries except the Cochran Formation.

Elsewhere within the province the trend of the radioactivity units parallels the regional strike, but the boundaries of the units do not appear to be related to the mapped geologic boundaries.

4.5 Summary

Natural radioactivity levels within the ORNL area ranged from 200 to 1400 cps. The Highland Rim has the lowest average radioactivity level, and the Great Smoky Mountains the highest, although all four provinces showed considerable range.

The radioactivity level of the Cumberland Plateau increases from southwest to northeast and from northwest to southeast. This is probably a reflection of the ratio of shale to sandstone and conglomerate which increases in the same directions.

In the Valley and Ridge province, some radioactivity units are continuous along strike from one side of the survey area to the other, a distance of 100 miles. Many can be traced for 50 miles or more. The Rome Formation, the Conasauga Shale, and the Clinch Sandstone are particularly well delineated by the radioactivity data. Middle Ordovician rocks grade from a principally carbonate sequence along the northwest side of the valley to mostly a shale sequence along the southeast side of the valley. The increase in shale content of these rocks to the southeast is reflected by the increasing radioactivity level of these rocks in that direction. In some areas where formations could not be separated owing to deep weathering between outcrops, the radioactivity data indicated where the contact should be.

In the Great Smoky Mountains, the radioactivity data generally could not be related to mapped geologic units. The boundary of the province, however, is approximately located by the sharp increase in radioactivity level compared to the levels in the Valley and Ridge province.

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