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AERORADIOACTIVITY SURVEY AND AREAL GEOLOGY OF THE SAVANNAH RIVER PLANT AREA, SOUTH CAROLINA AND GEORGIA (ARMS-I)

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ABSTRACT

A survey of 10,000 square miles near Augusta, Ga., was made by the U. S. Geological Survey for the U. S. Atomic Energy Commission. Continuous radioactivity profiles were obtained with scintillation-counting equipment at approximately 500 ft above the ground on parallel northwest-southeast flight lines spaced 1 mile apart. A map of aeroradioactivity units was prepared from the profiles. The gamma-radiation data indicates a wide range in the levels of natural radioactivity and that the levels are closely related to the types of underlying rock.

About 2000 square miles of the Piedmont province, partly mantled by thick residual soil, are included in the area. Three types of bedrock are present: a metamorphic complex of schist, gneiss, and granite; argillite, slate, and schist of the Carolina slate belt (Little River series of Crickmay[1]); and plutons of granite and porphyritic granite. The granites and parts of the metamorphic complex have a high aeroradioactivity; the aeroradioactivity of the slate belt is generally low. Several rock units in the Piedmont, irrespective of weathering, may be mapped by their characteristic radioactivity.

The Coastal Plain, consisting of several sedimentary units which range in age from Cretaceous to Quaternary, comprises the rest of the area surveyed. These rocks consist of soft sand, silt, clay, gravel, marl, and limestone. The aeroradioactivity of the Upper Cretaceous and Eocene rocks ranges from moderate to high whereas that of the younger beds is generally low.

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1. INTRODUCTION

1.1 Location of Area and Purpose of Survey

An aeroradioactivity survey of the Savannah River Plant area, South Carolina and Georgia, was made by the U. S. Geological Survey in cooperation with the Division of Biology and Medicine, U. S. Atomic Energy Commission. P. W. Philbin directed the survey which was made during July and August, 1958, as part of the Aerial Radiological Measurement Survey (ARMS) I program. The area studied was a square 100 miles on a side or 10,000 square miles centered at the Savannah River nuclear facility (Fig. 1).

The ARMS I-Savannah River survey is part of a nationwide program to obtain data on the existing gamma radioactivity for areas in and adjacent to nuclear facilities. These data provide information which can be used to detect any future variations in radioactivity which might result from nuclear testing, reactor or other Atomic Energy Commission operations, or radiation accidents.

1.2 Airborne-survey Procedure

The survey was made with scintillation-detection equipment installed in a twin-engine aircraft. Parallel northwest-southeast flight lines were spaced 1 mile apart and oriented perpendicular to the general geologic trend in the area. The aircraft maintained an approximate altitude of 500 ft above the ground at an average air speed of 150 mph. Topographic maps and county road maps were used for pilot guidance except in the plant area, where the U. S. Atomic Energy Commission map of the plant was used. 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 radiation and altimeter data and the

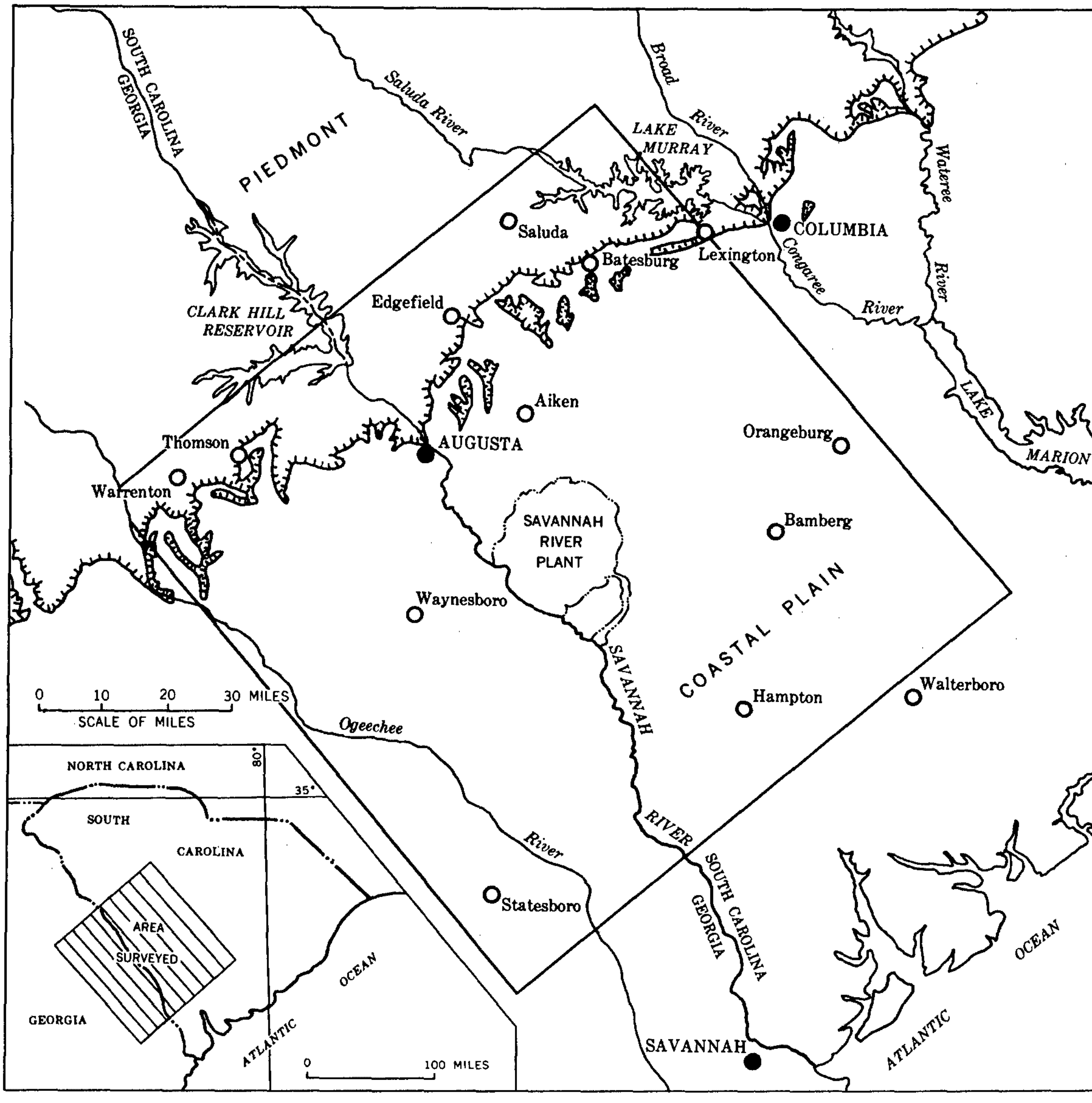


Fig. 1—Location of the Savannah River Plant area.

camera film were made with an electromechanical edge-mark system operated by the flight observer when the aircraft passed over recognizable features on the ground.

1.3 Scintillation-detection Equipment

The gamma radiation detection equipment used by the U. S. Geological Survey was designed by the Health Physics Division of the Oak Ridge National Laboratory and has been described in detail by Davis and Reinhardt[2]. They describe the sensitivity of the equipment in several ways, one being: "... with a microgram of radium at one foot from the crystals, the counting rate is roughly 2,000 cps (counts per second)". Kermit Larsen of the University of California, Los Angeles (written communication), determined in 1958 that a count rate of about 77,000 cps would be recorded by the U. S. Geological Survey equipment 500 ft above a virtually infinite area of fallout that produced a gamma-ray flux of 1 mr/hr (milliroentgen per hour) at 3 ft above the ground. This comparison was made over an infinite fallout source, the source being of infinite dimension insofar as the area of response of the airborne equipment is concerned.

A 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 originating from gamma radiation with energies greater than 50 kev (thousand electron volts). 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 that includes a variable resistance which is controlled by the radar altimeter servomechanism, thereby approximately compensating the data for deviations from the nominal 500 ft surveying altitude. The cosmic background is removed before the data are compensated. The range of topographic roughness handled satisfactorily by the compensator exceeds the irregularity of topography formed in the Savannah River Plant area. Compensated data were used in the preparation of this report.

The crystals are shielded on the sides by 0.5 in. of lead, which negates any influence of the radium-dial instruments in the aircraft. The effective area of response at an elevation of 500 ft is approximately 1000 ft in diameter, and the radiation recorded is an average of the radiation received from within the area. Theoretical aspects of the area of response and other considerations are discussed by Sakakura[3], Moxham[4], and Gregory[5].

The gamma-ray flux at 2000 ft above the ground, which comes from cosmic radiation and to a much lesser extent from radionuclides originating from the ground, is measured twice each day while surveying. This quantity is called the cosmic background at 2000 ft, and is removed from the altitude-compensated circuit. The average cosmic background measured at 2000 ft during the Savannah River Plant Survey was about 350 cps.

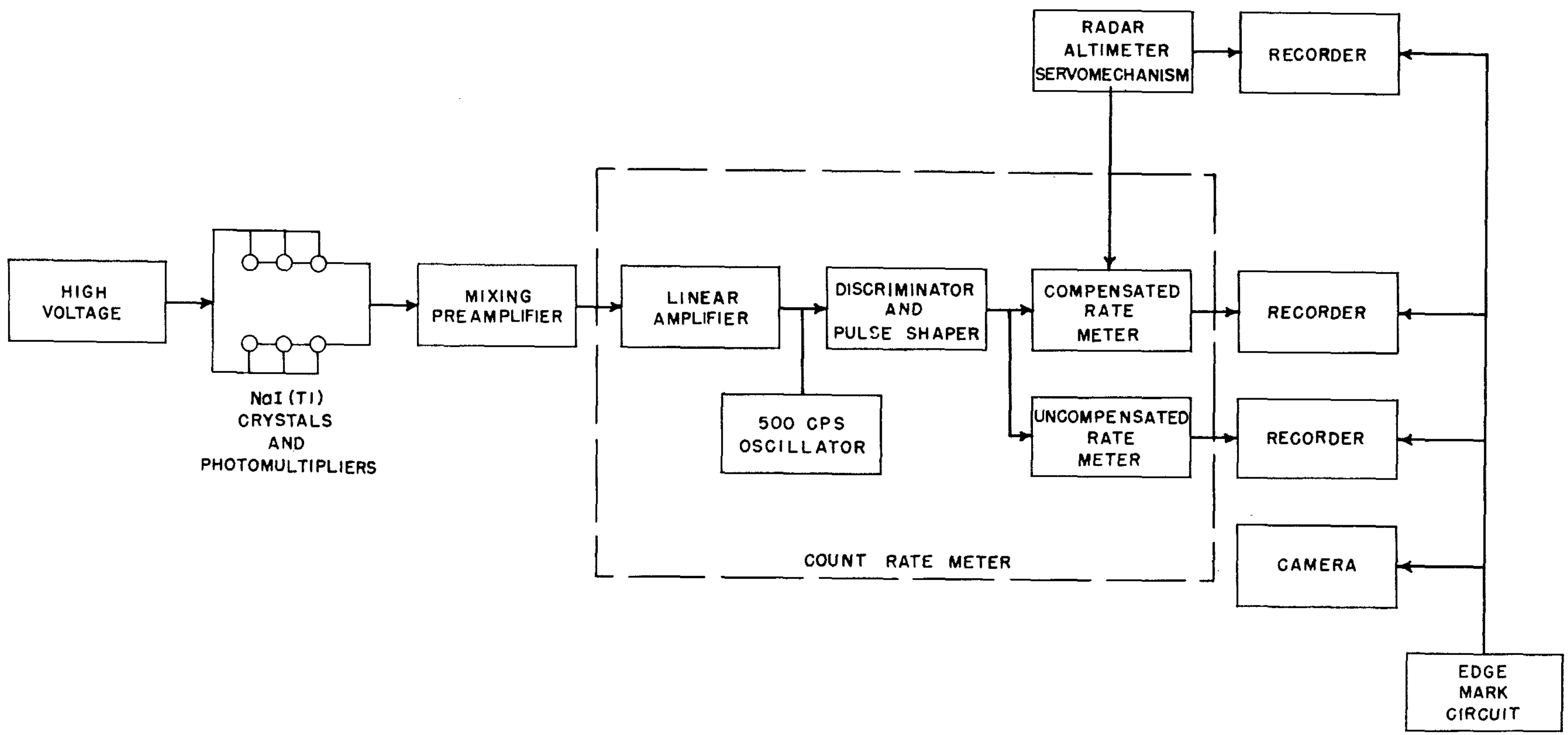


Fig. 2—Diagram of airborne radioactivity survey equipment.

1.4 Theoretical Considerations

The gamma-ray flux at 500 ft 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. As discussed in Sec. 1.3, it is possible to estimate the contribution of the cosmic component.

The component due to radionuclides in the air at 500 ft above the ground cannot be separated from that due to radionuclides in the ground. It is affected by meteorological conditions and a tenfold change in radon concentration is not unusual under conditions of extreme temperature inversion. However, the air component, if inversion conditions are avoided, may be considered to be fairly uniform on a given day in a particular area, and will not affect the discrimination of the aeroradioactivity units that reflect changes in the ground component.

The ground component consists of gamma rays from natural radionuclides (principally potassium-40 and members of the uranium and thorium radioactive decay series) in the upper 6 in. of the ground and radioactive fission products in fallout.

The activity due to fallout is a small part of the ground component in most places. Gustafson, Marinelli, and Brar[6], for example, concluded from a study of the radioactivity of soil from Lemont, Ill., that in the spring of 1957 the activity due to fallout was less than one-tenth the total gamma activity of the soil. Although Operation Plumbbob in 1957 produced considerable fallout, data from periodic resurveys of test lines in Virginia, Texas, and New Mexico by the U. S. Geological Survey (J. L. Meuschke, oral communication) indicate that fallout probably accounts for much less than 100 cps of the background gamma radioactivity in those areas. In the Savannah River Plant area, the amount of fallout must be small, as the lowest total radiation measured is 150 cps.

The present distribution and concentration of natural radionuclides in the surficial material are determined by the original content and form of the radioactive material in the parent rock and by changes brought about by geologic and soil-forming processes. An important consideration in studying the radioactivity of a soil is whether it is a residual soil which is derived from the rock beneath it, or a transported soil, which may be derived from rocks entirely different from that on which the soil rests. Complete studies of the distribution of natural radionuclides in the various soil and rock components of the surficial layer have not been made, but information on individual components is available. Radioactive heavy minerals, such as monazite, a rare-earth phosphate containing as much as 30 percent thorium, and zircon, a zirconium silicate containing as much as 1 percent uranium, are present in small quantities in many types of rocks and soils, and monazite is known to be unusually abundant in parts of the Savannah River Plant area.

The concentration of these minerals at the surface of a residual soil may be greater or less than their concentration in the parent rock, depending upon the interplay of the various soil-forming processes, but generally the radiation level measured is close to that of the bedrock. Uranium and thorium, and their daughter products, are commonly present in rock and soil in amounts ranging from traces to several parts per million. The content of all potassium isotopes of the surficial layer may be as much as several percent, of which potassium-40 (the only naturally occurring radioactive potassium isotope) is only a minute part. Rough averages for the amounts of these elements in common rocks in parts per million are shown in Table 1 (adapted from Turekian and Wedepohl[7]).

Table 1 — APPROXIMATE AMOUNTS OF URANIUM, THORIUM, AND POTASSIUM-40 IN COMMON ROCKS

Rock	Uranium, ppm	Thorium, ppm	Potassium-40, ppm
Granitic rock	3	8.5-17	3-5
Basaltic rock	0.001	4	1
Sandstone	0.45	1.7	1.3
Shale	3.7	12	3
Carbonate rock	2.2	1.7	0.3

1.5 Ground Survey

A reconnaissance study of the radioactivity was made on the ground and it was found that the variations recorded are intimately related to the geology of the area. In certain places the aeroradioactivity data could be used to map geologic units quite precisely, even though the rocks are generally mantled by a thick residual soil cover. The radiation measured 1.5 ft above the ground with a scintillation counter ranged from 0.01 to 0.17 mr/hr including cosmic background. The smallest ground reading corresponded to 150 cps measured in the air, 0.05 mr/hr on the ground corresponded to 1700 cps in the air (Fig. 3). The gamma radiation recorded at 500 ft above the ground in the Savannah River Plant area ranged from 150 to 2100 cps.

A ground reconnaissance study was made to determine the relations between the gamma radiation recorded in the air and that recorded for the soils and rocks in the area. In general the available geologic maps of the Coastal Plain are better than those in the Piedmont; whereas the greatest variations in radioactivity are found in the Piedmont. As a result it was necessary to spend most of the time in the field studying the Piedmont areas of both Georgia and South Carolina. The ground study was almost entirely confined to localities close to public roads. The soils, saprolites, and rocks examined in the ground reconnaissance were described and sampled, and radioactivity was measured with a hand contour (Fig. 3). Several soil samples and counter readings were obtained from units of relatively uniform radioactivity at points directly under the course of the

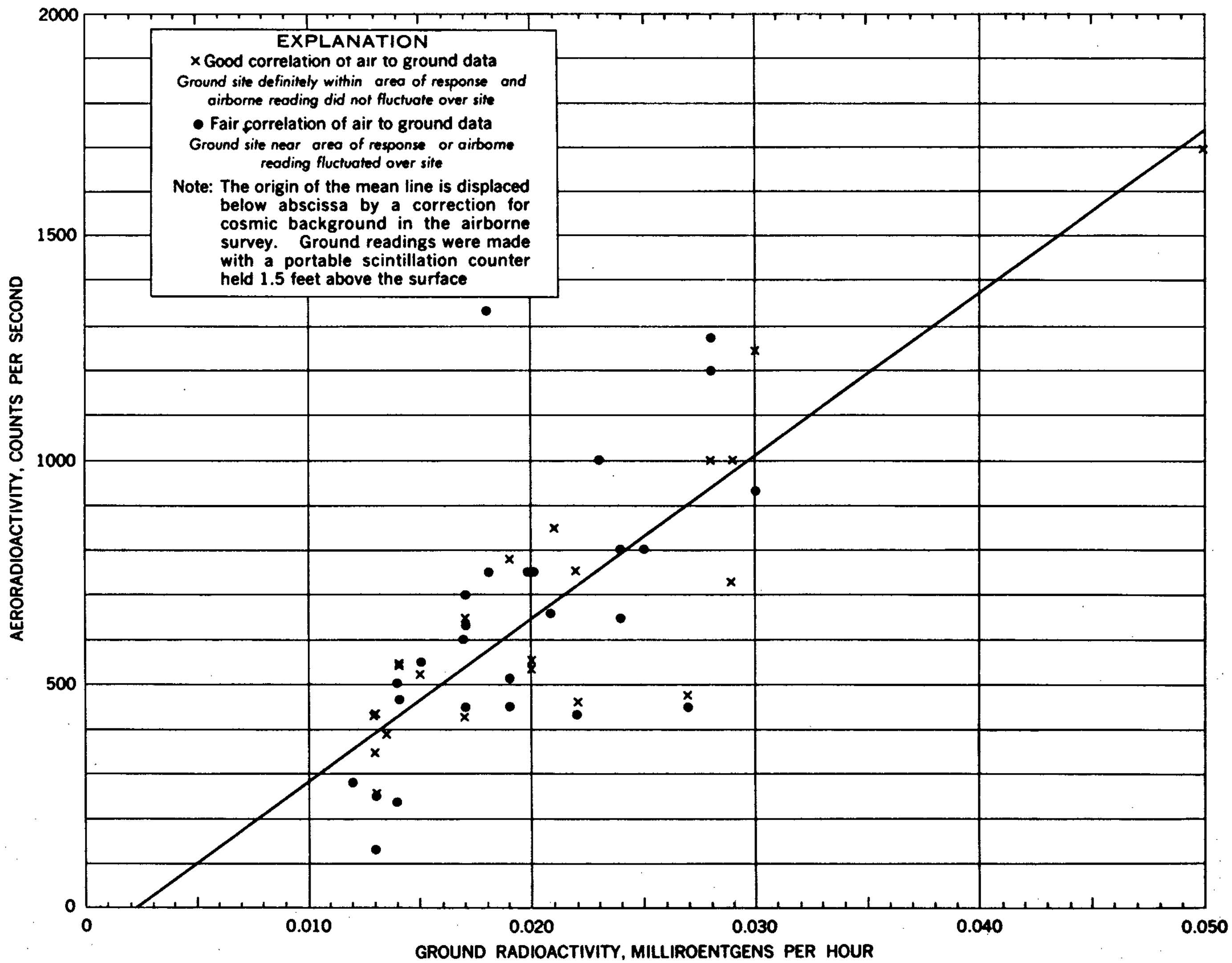


Fig. 3—Aeroradioactivity compared with scintillation counter readings made on the ground at 49 places in South Carolina and Georgia.

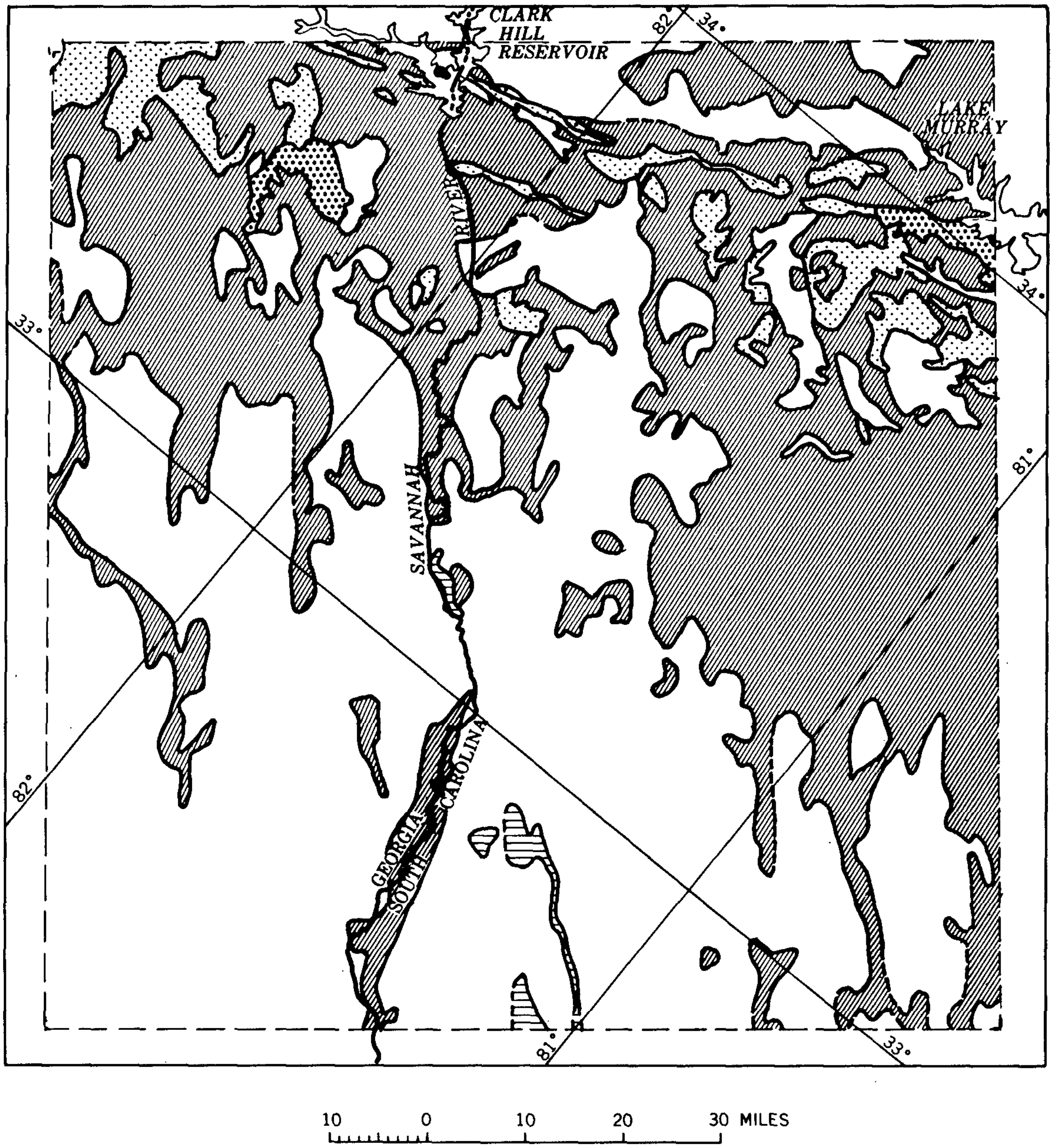
aircraft. The observations shown on Fig. 3 indicate a count rate of about 360 cps for an increment of 0.01 mr/hr measured on the ground.

1.6 Compilation of Aeroradioactivity Data

The altitude-compensated aeroradioactivity profiles were used in the preparation of the map "Natural gamma aeroradioactivity of the Savannah River Plant area, South Carolina and Georgia" (in pocket). This map is also published in the U. S. Geological Survey Geophysical Investigations Map Series[8].

Flight line locations from the strip-film obtained during the course of surveying were plotted on the compilation base maps (scale 1 in. equals about 1 mile). Radioactivity profiles from adjacent flight lines were examined and changes or breaks in the level of the radioactivity record were correlated from line to line. The changes of the radioactivity record are indicated on the map (in pocket) by solid or dashed lines, dependent on the degree of correlation. The difference between the lines is a matter of degree, the solid lines denoting distinct changes in level of radioactivity, the dashed lines relatively less distinct, generally transitional changes. Areas between the lines of change were assigned general ranges of radioactivity levels by scanning the records obtained over the specific areas. The lines of change and the radioactivity levels were plotted along flight lines on transparent overlays of the compilation base maps. These overlays were reduced to a scale of 1 in. equals about 4 miles (1:250,000) and the data plotted on sheets of the Army Map Service, Corps of Engineers 1:250,000-scale topographic map series. The final map (in pocket) was thus derived, showing radioactivity levels and lines of change and major cultural and drainage features. The varying patterns of green on the map indicate approximate ranges of radioactivity, and are meant to facilitate reading of the map. Fig. 4 is a generalized version of the same map.

After the altitude-compensated aeroradioactivity data were plotted on the compilation base maps, it was found necessary to apply empirical corrections to certain lines to make the aeroradioactivity levels on adjacent lines compatible and to make the levels on test lines uniform on consecutive days. These corrections, which were as much as $\pm$ 150 cps, were applied to part of or all the lines flown on July 7, 9, 17, and 21, and August 6 and 7 (Table 2). The corrections were based on readings obtained over open water wherever possible, otherwise by the reading over standard test lines, or by comparison with adjacent lines where no other standard was available. The reasons necessitating these empirical corrections are not completely understood, but several things may by considered as possible contributing factors: (1) meteorological conditions, particularly an inversion layer during part or all of a day, (2) changes in the source, such as water in the soil decreasing the radiation from the ground or radioactive fallout increasing the background, and (3) errors in the procedure of making the daily instrumental correction. It is believed that most of the day-to-day changes in background radioactivity are related to changes in the concentration of radon or to changes in the amount of water in the soil. Changes in the background from one day to another cause a shift in the general aeroradioactivity level, but



EXPLANATION

Gamma radiation in counts per second

0-200 200-450 450-700 700-1000 1000-1500

Boundaries of aeroradioactivity units
Dashed where not well defined

Fig. 4—Generalized aeroradioactivity map of the Savannah River Plant area.

they are not believed to affect the discrimination of the aeroradioactivity units that reflect changes in the ground component and, if properly corrected, do not seriously affect the total counts measured.

Table 2 — EMPIRICAL CORRECTIONS APPLIED TO SAVANNAH RIVER AERO-RADIOACTIVITY DATA*

Date (1958)	Flight lines (in order flown)	Correction applied before compilation of maps
July 7	<u>47</u>, 48, <u>49</u>, 50	Line 50 is 100 cps high
8	<u>51</u>, 52, <u>53</u>, 54	None
9	<u>55</u>, 56	All 50 cps low
11	<u>57</u>, 58, <u>59</u>, 60	None
14	<u>61</u>, 62, <u>63</u>, 64	None
16	<u>46</u>, 45, <u>44</u>, 43	None
17	<u>42</u>, 41, <u>40</u>, 39	All 150 cps high
21	<u>38</u>, 37	All 100 cps high
22	<u>36</u>, 35, <u>34</u>, 33	None
23	<u>65</u>, 66, <u>67</u>, 68	None
24	<u>69</u>, 70	Seem high
25	<u>32</u>, 31	Line 31 seems low
26	<u>71</u>, 72, <u>73</u>, 74	None
27	<u>75</u>, part of 76	None
28	Part of 76, <u>77</u>, 78, <u>79</u>, 80, <u>81</u>, 82	None
Aug 1	83, <u>84</u>, 85, <u>86</u>, 87, <u>88</u>	None
2	89, <u>90</u>, 91, <u>92</u>	None
5	93, <u>94</u>, 95, <u>96</u>	None
6	97, <u>98</u>, 99, <u>100</u>	Line 99 is 50 cps high, line 100 is 100 cps high
7	15	100 cps high at northwest end
8	<u>30</u>, 29, <u>28</u>, 27, <u>26</u>, 25	None
11	<u>24</u>, 23, <u>22</u>, part of 21	None
12	Part of 21, <u>20</u>, 19, <u>18</u>, 17, <u>16</u>, 14	Lines 20, 19, 18, 17, and 16 are low
13	<u>13</u>, 12, <u>11</u>, 10, <u>9</u>, 8	Line 13 is low
14	<u>7</u>	None
15	<u>6</u>, 5, <u>4</u>, 3, <u>2</u>, 1	None

*Lines flown in southeast direction are underlined; lines flown in northwest direction are not underlined.

2. GENERAL GEOLOGY

The Savannah River Plant area is located in two major physiographic provinces, the Coastal Plain, underlain by gently dipping sedimentary rocks, Late Cretaceous to Quaternary in age; and the Piedmont, underlain by steeply inclined metamorphic and igneous rocks, probably of Precambrian or Paleozoic age (Fig. 5). About 8000 square miles of the area lies in the Coastal Plain and 2000 square miles in the Piedmont (Fig. 1). The strike of the rocks is generally N60°E in both the Piedmont and the Coastal Plain.

A geologic map of the Savannah River Plant area was compiled from published maps and descriptive data and from field observations made in this study (Fig. 6). A large part of this geologic map, especially in the Piedmont and in the South Carolina Coastal Plain is provisional. Boundaries of the Coastal Plain formations in most of the area in South Carolina are the result of interpolating and extrapolating the contacts from a few data described in the literature and using approximate regional dips and generalized topography. This procedure was followed because the geologic maps available were outdated by other geologic information, especially by the publication of "Tertiary Stratigraphy of South Carolina" by Cooke and MacNeil[9]. The level of natural radioactivity was used as an additional guide in preparing the Piedmont part of the geologic map, but it was not generally useful in studying the formation boundaries in the Coastal Plain.

Three types of rocks are present in the Piedmont: (1), a metamorphic complex of slate, schist, gneiss, and granite; (2), argillite, slate, schist, and quartzite of the Carolina slate belt which is also called the Little River series[1]; and (3), plutons of granite and porphyritic granite. The Piedmont rocks are mantled by deeply weathered rock or saprolite, and residual soil over most of the area; hard rock outcrops are uncommon except in streams and highway cuts.

The Coastal Plain is underlain by sedimentary rocks that dip gently toward the Atlantic Ocean. In general the older layers are exposed along the northwest side of the Coastal Plain and successively younger formations occur toward the ocean. The formations consist mostly of sand, silt, clay, marl, and limestone.

3. GENERAL DISTRIBUTION OF AERORADIOACTIVITY

There is a definite correlation between the type of bedrock and the general intensity of natural gamma radiation, but there are many exceptions to this broad generalization. In the Piedmont, relatively low aeroradioactivity (generally 300 to 600 cps) is associated with both parts of the Carolina slate belt, and high aeroradioactivity (generally 700 to 1800 cps) is associated with the granites. The metamorphic complex includes areas of both high and low intensity. No particular reason for the distribution of aeroradioactivity within

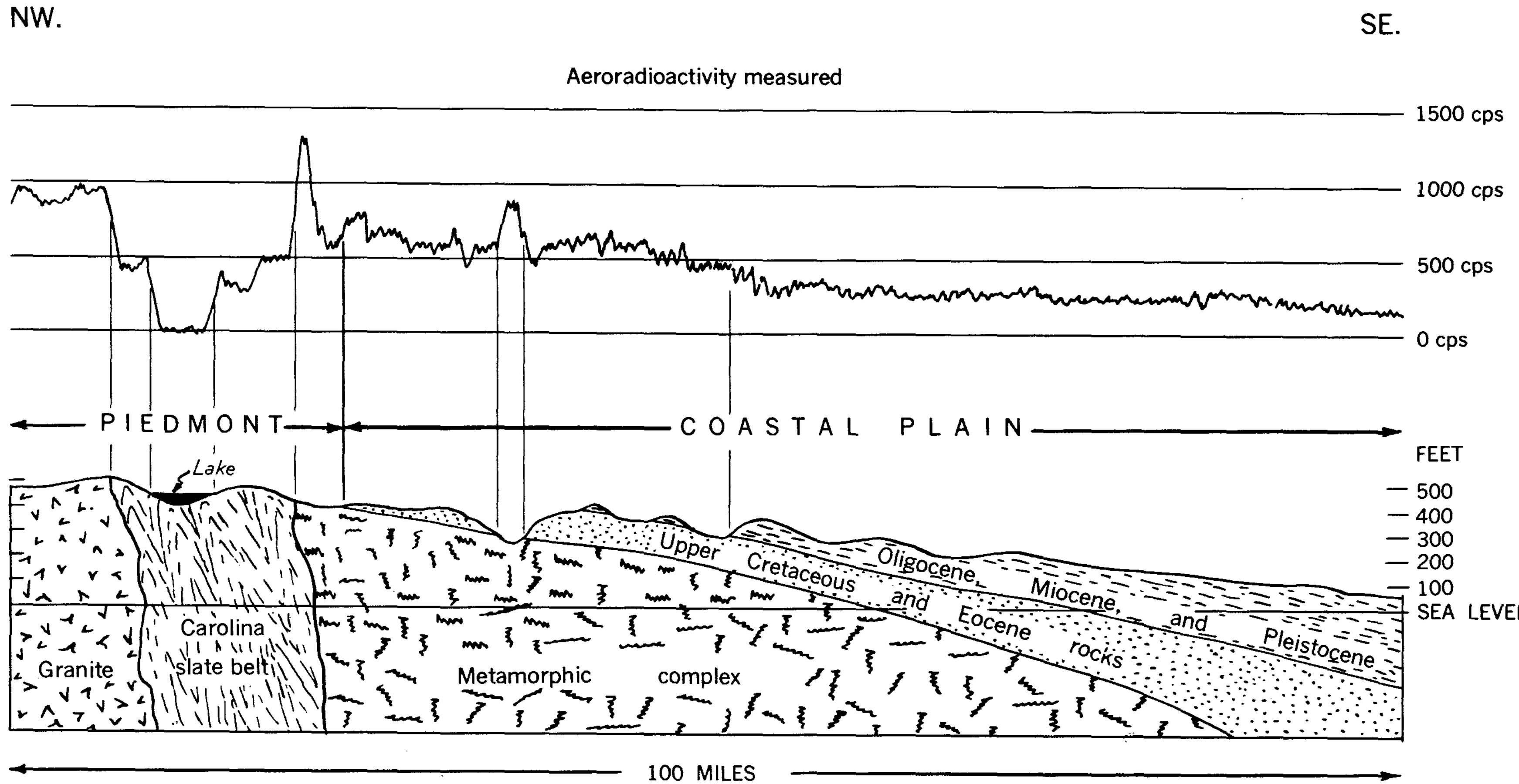


Fig. 5—Diagrammatic cross section of the rocks in the Savannah River Plant area and typical associated aeroradioactivity.

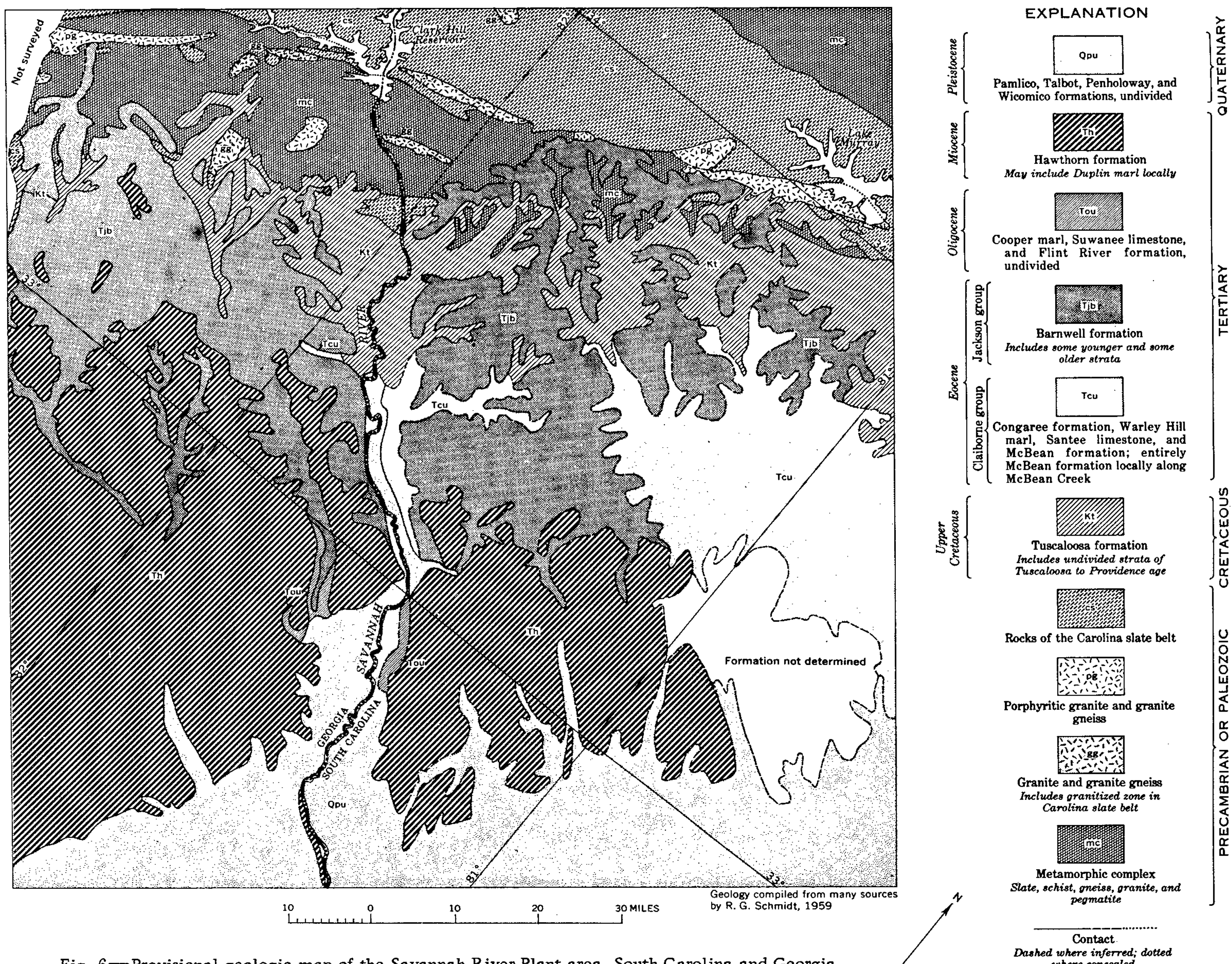


Fig. 6—Provisional geologic map of the Savannah River Plant area, South Carolina and Georgia.

the metamorphic complex could be found. The highest natural gamma radioactivity measured in the airborne survey was 2100 cps which was recorded over the complex in western Columbia County, Ga. A nearby area of 1900 cps was checked on the ground with a hand counter which showed a range of 0.03 to 0.1 mr/hr, averaging about 0.05 mr/hr.

The Coastal Plain is generally less radioactive than the Piedmont but a great range in aeroradioactivity was recorded. The older Coastal Plain formations (those farthest from the ocean, the Upper Cretaceous and Eocene) are the most radioactive and generally range from 400 to 800 cps. Many areas in Lexington and eastern Aiken Counties, S. C., mostly containing Upper Cretaceous rocks, are much higher in radioactivity and range from 700 to 1300 cps. The younger Coastal Plain formations, Miocene through Pleistocene, are the least radioactive in the Savannah River Plant area and generally range from 300 to 600 cps.

4. GEOLOGY OF THE PIEDMONT

The metamorphic complex occurs in two parts of the area studied, in the northernmost corner of the area north of Lake Murray (Fig. 6), and in a belt trending nearly parallel to the Fall Line. A small part of the southern belt is covered by overlapping younger Coastal Plain rocks in Georgia, but in South Carolina it is largely covered by these rocks. The southeast edge of this belt of the metamorphic complex is exposed where larger stream valleys have been cut through the Coastal Plain.

The metamorphic complex consists mostly of schist and gneiss with many small bodies of granite and gneissic granite. There are inclusions of argillacous rock similar to that of the Carolina slate belt and earlier reports have mentioned occurrences of quartzites. Dark mafic rocks occur in many places and two prominent hills in northeastern Columbia County, Ga., are underlain by serpentine. No attempt was made to subdivide the complex because the units of which it consists (schist, gneiss, and intrusive granite) all occur intimately associated over the entire area in which the complex is found. Several areas formerly mapped as granite plutons in the complex[10] were found to include large amounts of schist and paragneiss and are here considered part of the complex. Some of the highly metamorphosed rock has probably been derived by metamorphism of the Carolina slate belt, although some of the complex is probably older than the Carolina slate belt.

The slate, schist, and part of the gneiss of the metamorphic complex are steeply inclined, intensely folded, and intruded by small masses of igneous rock, particularly granite.

Rocks of the Carolina slate belt occur in two major zones which extend across the entire Savannah River Plant area. One is between the two areas of the metamorphic complex described above and is extensively exposed from Lake Murray to Clark Hill Reservoir and the west corner of the area. Rocks of the Carolina slate belt have been called the Little River series in Georgia[1]. South of this belt and separated from it by the southern belt of the metamorphic complex is another zone of slate belt rocks. The second zone is only exposed in stream valleys and is probably not continuous but is interrupted by granite and gneiss.

The Carolina slate belt consists of argillite, slate, schist, and quartzite. These are folded and mostly dip at a high angle. The bedding and cleavage are generally parallel. The metamorphic grade is low, probably chlorite or biotite grade over most of the belt.

The Carolina slate belt is said to be derived by metamorphism of material that consists in part of tuffs, tuffaceous sedimentary rocks, and flows[10]. The tuffs and flows were believed to have been rhyolitic and andesitic by Kesler[11]. No evidence bearing on the origin of the slate was found in the field reconnaissance, except that some seems tuffaceous, and the titanium content of some is anomalously high.

Granite, granite gneiss, and porphyritic granite and gneiss underlie many small irregularly shaped areas in the metamorphic complex and the Carolina slate belt. Only a few granite masses, however, are large enough to be shown on Fig. 6, and within the metamorphic complex they are differentiated from those granites included in the complex only because they are large enough to be mapped separately. Most of the mapped granite masses are probably intrusive into the rocks that enclose them.

5. GEOLOGY OF THE COASTAL PLAIN

Formations in the Coastal Plain of South Carolina and Georgia range from Late Cretaceous to Pleistocene in age. The formations dip very gently southeast and south and consist mostly of sand, silt, clay, gravel, marl, and limestone. Several geologists have described the stratigraphic succession in detail, and the rocks of the Coastal Plain are on the whole better known than those in the Piedmont.

The areal distribution of the Coastal Plain formations in South Carolina is known in detail only in the Warrenville and Aiken quadrangles and the northern one-third of the Augusta and Talatha quadrangles which were mapped by Lang[12]. The general distribution of the Coastal Plain formations in the rest of South Carolina was shown by Cooke[13] and several changes in Cooke's map were described by Cooke and MacNeil[9]. Fig. 6 shows a provisional areal distribution of the formations as adapted from Cooke[13] and incorporating the changes described by Cooke and MacNeil[9], the formational boundaries adjusted to the topography. Further changes in the areal distribution of the Hawthorn formation were described by Siple[14] but not enough information was given to permit its inclusion in Fig. 6.

Cooke[13] presented the distribution of Upper Cretaceous and Tertiary strata and the Pleistocene formations on separate maps, and, in combining these maps here, only the Pleistocene Wicomico and younger formations were shown. It is known that the Hawthorn formation of Miocene age is extensively mantled by Pleistocene material older than Wicomico, especially in Hampton and Allendale Counties, but the author could find no basis for showing the limits of these areas. Patches of Pleistocene materials also cover areas mapped as Claiborne and Jackson groups.

The Coastal Plain formations of Georgia have been mapped in detail by Cooke[15, 16], MacNeil[17], Eargle[18], and LeGrand and Furcron[10]. The map by LeGrand and Furcron was used with slight modification in preparing the Georgia Coastal Plain part of the geologic map of the Savannah River Plant area.

5.1 Tuscaloosa Formation

The irregular outcrop belt of the Tuscaloosa formation of Late Cretaceous age extends entirely across the northwest side of the Savannah River Plant area. The formation strikes northeast and dips southeast about 28 ft per mile. The strata included in the Tuscaloosa here almost certainly embrace a much greater span of geologic time than the most strictly defined formation in southwestern Georgia.

The thickness of the formation near the outcrop is as much as 150 ft in Georgia and in South Carolina and increases downdip to about 800 ft measured in wells near the Atlantic Coast. The formation consists of gray, red brown, tan, and white arkosic sand, and lenses of vari-colored clay. Clay is present in much of the sand and is locally abundant, forming a clay-cemented sandstone or sandy clay. The lenses of clay are locally thick and pure and high-quality kaolin is mined at many places in the area[12]. Angular quartz gravel is common, generally near the base. Although part of the sand is massive, abundant cross-bedding, lensing, and channeling tend to distinguish this formation from younger units.

5.2 Claiborne Group

The Claiborne group of middle Eocene age is extensively exposed in the Savannah River Plant area in Orangeburg and Calhoun Counties, S. C., and occurs locally in Aiken County, S. C., and in some very small areas along the Savannah River and Briar Creek in Georgia. The group in the Savannah River Plant area consists mostly of the McBean formation but locally includes the Congaree formation, the Warley Hill marl, and the Santee limestone, all of Claiborne age.

The Claiborne group strikes about east-west and dips southward. It increases in thickness downdip from perhaps 75 or 100 ft at the outcrop to 450 ft in an oil test well near Savannah, Ga.

The Claiborne group consists of massive yellow, red, and greenish sands, thin layers of white marl and greenish glauconitic marl, fuller's earth, limestone, and hard, brittle siltstone. The Warley

Hill marl and Santee limestone are more limy than the McBean and Congaree formations.

5.3 Jackson Group

The Jackson group is represented in the Savannah River Plant area by the Barnwell formation that occurs extensively in the higher Coastal Plain in both Georgia and South Carolina. The Barnwell formation strikes about N60°E and dips very gently southeastward--dips of 9 and 13 ft to the mile have been given in the literature. It is thin, ranging in thickness from 70 to about 200 ft in Georgia and from 10 to about 100 ft in South Carolina.

The Barnwell formation is largely made up of buff to deep red argillaceous sand, and bright red sand is the most common. The formation also includes clay layers and beds of shelly marl and clay. There is at least one limestone bed and residual pieces from several others in the Barnwell formation. Siple[14] suggested that the Barnwell was originally a sandy limestone and that the lime has been mostly leached out. Subsidence resulting from solution of calcareous material has caused disarrangement of the overlying beds[10].

5.4 Oligocene Formations

The Cooper marl, Suwanee limestone, and Flint River formation occur in a limited area near the Savannah River in South Carolina and Georgia and near Bamberg and Branchville in South Carolina. The formations have been reported from a number of localities, but there is little information about the actual areal extent of each.

The Cooper marl has been regarded as Eocene by some authors, but the early Oligocene classification of Cooke and MacNeil[9] is used here. The Cooper marl is a cream to grayish-green calcareous clay or soft limestone. It is glauconitic and phosphatic and as much as 150 ft thick. Phosphate is locally concentrated in the form of nodules near the surface. The Cooper marl may underlie a large part of the area on Fig. 6 for which the bedrock formation is not known.

The Suwanee limestone is a very thin formation shown by MacNeil[17] to occur in this area only in Georgia in southeastern Burke and northern Screven Counties. It is probably at least partly equivalent to the Flint River formation. It ranges from friable and granular to hard and is generally yellowish or cream. The thickness of this formation probably does not exceed 20 ft.

Of the Flint River formation only residual clay, sand, gravel, and silicified limestone remain within the Savannah River Plant area. Chunks of silicified limestone ("chert") are the residual material most readily recognized. The unleached rock ranged from pure limestone to sandy and pebbly limestone, sand, and gravel[16]. The thickness of the unleached rock is not reliably known, perhaps being between 70 and 148 ft[16]. The Flint River formation has been identified at several localities near the Savannah River in Georgia and South Carolina north of Sylvania, Ga., and west and southwest of Allendale, S. C.

5.5 Miocene Formations

The Miocene formations are the very widespread Hawthorn formation and the Duplin marl.

The Hawthorn formation crops out or is close to the surface in a large part of the Savannah River Plant area, about half the Coastal Plain in Georgia and a quarter of the Coastal Plain in South Carolina, even though it may not exceed 160 ft in thickness. It consists of several rather diverse facies. Sandy phosphatic limestone, sandy clay, gravel, fuller's earth, and brittle shale are common lithologic types. Sandstone and calcareous clay are also present, and dolomitic limestone, found in southwestern Georgia, may extend into the Savannah River Plant area. Siple[14] describes locally abundant clastic dikes filled with silty or sandy clay.

The Hawthorn formation was shown by Cooke[13] to extend northwestward only into the edge of Allendale County, but Cooke and MacNeil[9] presented additional information to show that the formation extended much further so that it covers much of Allendale County and extends well into Barnwell County and northern Bamberg County. Siple[14] further extended the Hawthorn formation northwestward across Upper Three Runs about 2 miles south of Talatha, or about 14 miles south of Aiken.

The Duplin marl occurs in the Savannah River Plant area where it is found along the Savannah River near the Effingham-Screven county line, Ga., and possibly also near the Edisto River, S. C. The marl was thin when originally deposited and has since been largely eroded away. Along the Savannah River the thickness ranges from 5 to 12 ft[16].

As previously mentioned, the area provisionally mapped as Hawthorn formation on Fig. 6 is extensively mantled by Pleistocene formations. Because there is almost no information regarding the areal extent of the Pleistocene cover, the area above 100 ft in elevation (Wicomico terrace) is shown as Miocene or older.

5.6 Pleistocene Deposits

At least 1500 square miles along the southeast edge of the Savannah River Plant area is covered with Pleistocene sedimentary material (Fig. 6), and many unmapped areas of Pleistocene material lie on the older Coastal Plain formations. Though the Pleistocene deposits in South Carolina and Georgia have been divided into several formations, subdivision of the deposits does not seem justified in this study. The Pleistocene formations consist of near-shore marine deposits of sand and clay. The younger formations contain finer material than the older, much of the substance of the younger deposits having been derived from the older formations[13].

6. DETAILED DISTRIBUTION OF AERORADIOACTIVITY

A large range in the gamma aeroradioactivity, from 150 to 2100 cps, was found in the Savannah River Plant area. Although some of the radiation may be due to a uniform blanket of fallout, the great range described here and shown on the 1:250,000 map is almost certainly due to natural variations in the surficial materials and the radiation measured is regarded as derived from natural sources. The aeroradioactivity within the Savannah River Plant reservation is shown in Fig. 12 and discussed in Sec. 6.3.

The highest natural radiation measured occurred in the Piedmont Province, and the Piedmont is generally more radioactive than the Coastal Plain, but the total range in aeroradioactivity is great in each, 250 to 2100 cps over the Piedmont and 150 to 1300 cps over the Coastal Plain. In the southeastern Coastal Plain there are many areas of wooded swampland in which the shielding effect of standing water under the trees reduced the measured radiation to 50 or 100 cps.

6.1 Distribution of Radioactivity Relative to Geology in the Piedmont

The areas of lowest aeroradioactivity in the Piedmont are underlain by rocks of the Carolina slate belt and of the highest aeroradioactivity by granites and highly metamorphosed sedimentary rocks. The aeroradioactivity of the slate is generally low, and locally, where the slate is bounded by a granite or other more radioactive rock, the line of radioactivity change is an accurate trace of the geologic contact. The slate belt-granite contact in an area in Lexington County, S. C., is shown in Fig. 7. In this same illustration the radioactivity measured over the granite also contrasts with that measured over the Coastal Plain. Although the sinuous contact between the granite and the overlapping Tuscaloosa formation could not be delineated with data from flight lines spaced 1 mile apart, a good break in level appears on many profiles where the contact is crossed.

In Saluda and Edgefield Counties, S. C., a large area of the Carolina slate belt was covered by the survey. The slate was found in the field reconnaissance to be of generally uniform composition and metamorphic grade but the aeroradioactivity survey indicates a zoning that parallels the regional strike of the slate belt. Fig. 8 shows part of this area divided into three general zones. Zone 1 (400 to 550 and 400 to 600 cps) occurs in two main belts. Zone 2 (300 to 400 cps) is roughly 3 miles wide and lies between the belts of zone 1. The large southward bulge in the zone 1-zone 2 boundary near the center of Fig. 8 is controlled by the data of only one flight line (there is another similar bulge just outside the area of Fig. 8 on the west). As the radiation measured in zone 1 is not greatly different from that

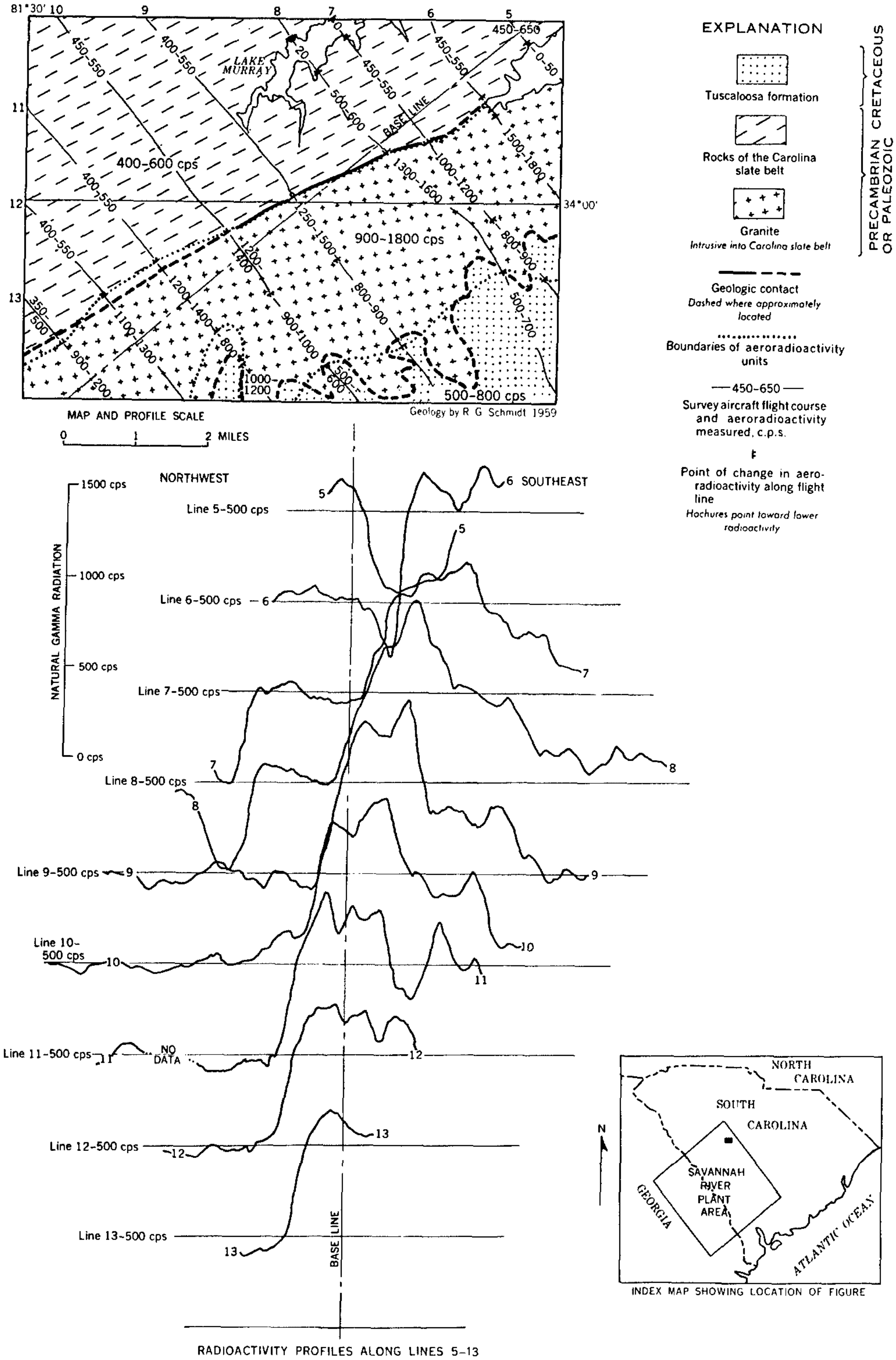


Fig. 7—Geologic and radioactivity map and radioactivity profiles of an area in Lexington County, South Carolina.

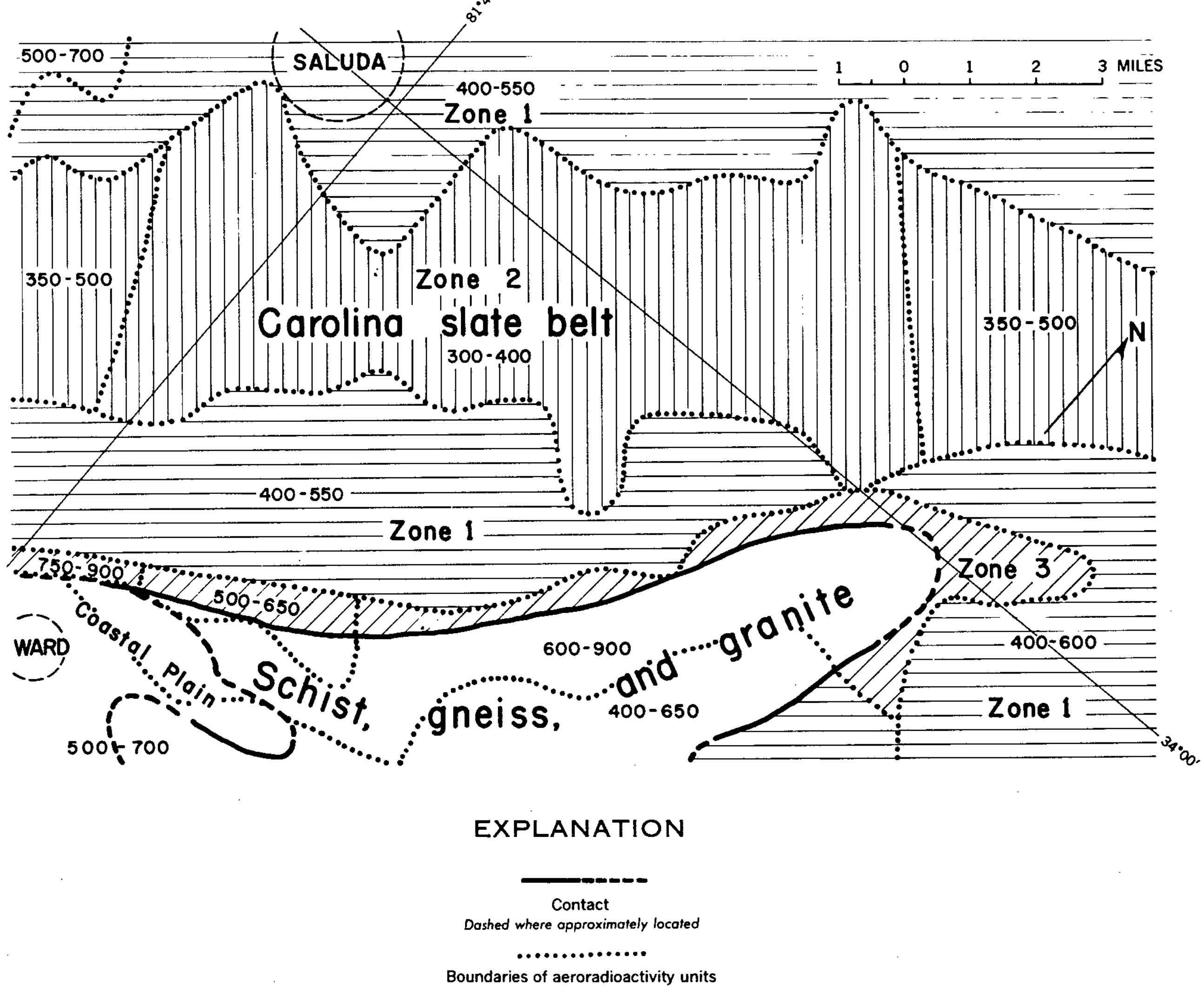


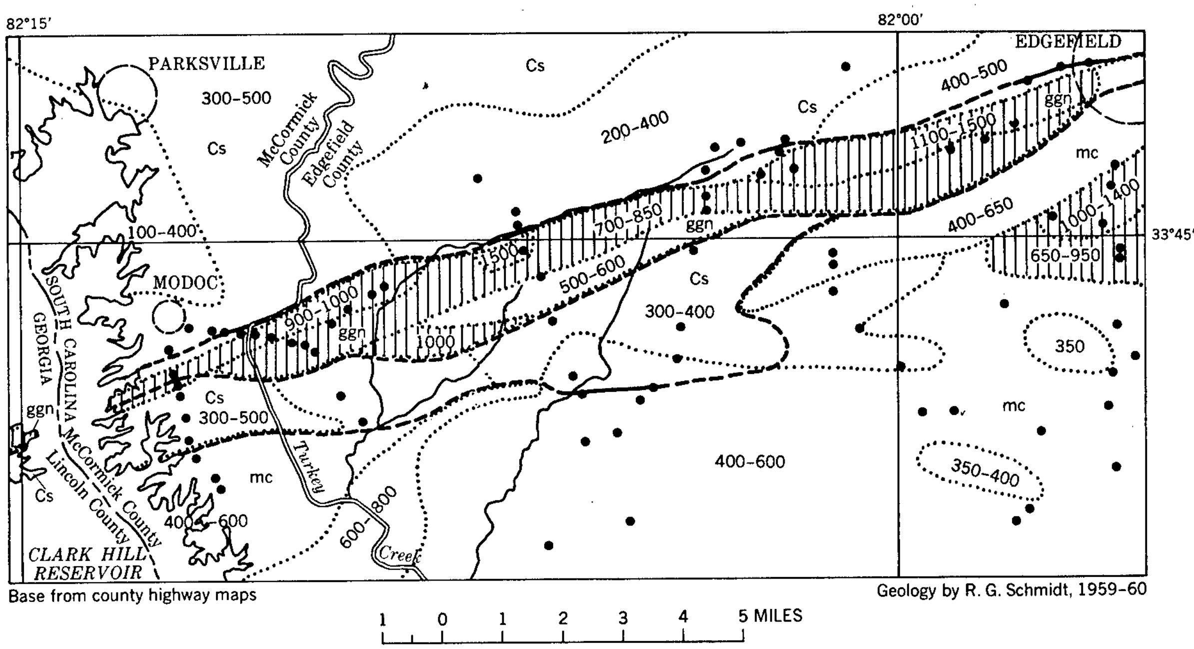
Fig. 8—Map showing zones of radioactivity in the Carolina slate belt, Saluda County, South Carolina.

measured in zone 2, the local displacement of the boundary is not considered significant. Zones 1 and 2 form parallel adjacent belts for more than 35 miles; zone 1 disappears westward and zone 2 disappears eastward. No difference in the rocks of the two slate belt zones could be seen in the field: colors, textures, and metamorphic grade appeared similar throughout. Zone 3 is a half-mile wide belt of higher radioactivity that closely parallels the edge of the belt. This radioactive zone was studied in the field, but there is no clear reason for the higher radioactivity. The zone was found to be generally similar to the rest of the slate belt, but at two places the rock appeared tuffaceous and at three places a rapid field test showed the rock contains about 2.0 percent titania, which suggests a pyroclastic origin.

A radioactive area in Edgefield and McCormick Counties, S. C., extends from the west side of the town of Edgefield southwestward to Clark Hill Reservoir, and also slightly beyond into the southeast part of Lincoln County, Ga. This belt is as much as 1.5 miles wide and 16 miles long (Fig. 9). The area was checked at several places in a rapid field examination and it was found to consist of ordinary Carolina slate belt rocks and narrow, possibly lenticular, gneissic granitic migmatized zones. The migmatized gneiss bands are a few tens to perhaps 1500 ft wide, and the strips of intervening slate are probably of similar width. The continuity of the strips is not known. The area of high radioactivity is generally confined to that area in which the granitic migmatite has developed. The same area is also more extensively cultivated than the surrounding country as shown on aerial photographs. The U. S. Department of Agriculture soils map of Edgefield County indicates that the soils types in the area are similar to the metamorphic complex to the south and are unlike the slate belt farther north.

A long narrow area of high aeroradioactivity was investigated in southern McCormick and central Edgefield Counties (Fig. 10). Toward the western end, this high area was found to be underlain by a biotite granite containing fairly abundant plagioclase. Both the saprolite and soil over this granite are as radioactive as the fresh rock. A similar granite was found within the highly radioactive zone (800 to 1400 cps) 5 miles east on the main highway near Stevens Creek. It is assumed for the purposes of reconnaissance mapping that the granite is continuous between the two sites and that the area underlain by granite is approximately the same as the area of high aeroradioactivity. No exposures of fresh rock or saprolite could be found in the radioactive zone on a brief survey east of Stevens Creek, but the granite has been mapped as continuing 3 miles eastward to a point where the radioactivity diminishes and the anomalous zone narrows to about a quarter mile. Anomalously high aeroradioactivity (600 to 850 cps and 850 to 1100 cps) occurs along the same trend to the edge of the overlying Coastal Plain, and further geologic field work might establish the presence of the granite along the entire zone to the Coastal Plain.

An area of high aeroradioactivity (mostly 800 to 1100 cps) is associated with a large mass of porphyritic granite southeast of



EXPLANATION

Cs

Rocks of the Carolina slate belt

mc

Metamorphic complex

Slate, schist, gneiss, granite, and pegmatite

ggn

Granitized gnessic zones in the Carolina slate

PRECAMBRIAN OR PALEOZOIC

Contact

Dashed where inferred from widely spaced exposures and aeroradioactivity

Boundary of aeroradioactivity unit

200-400

Aeroradioactivity in counts per second

Units over 650 cps are vertically lined

Places where rocks were examined in the field

Fig. 9—Provisional geologic and aeroradioactivity map of an area near Edgefield, South Carolina.

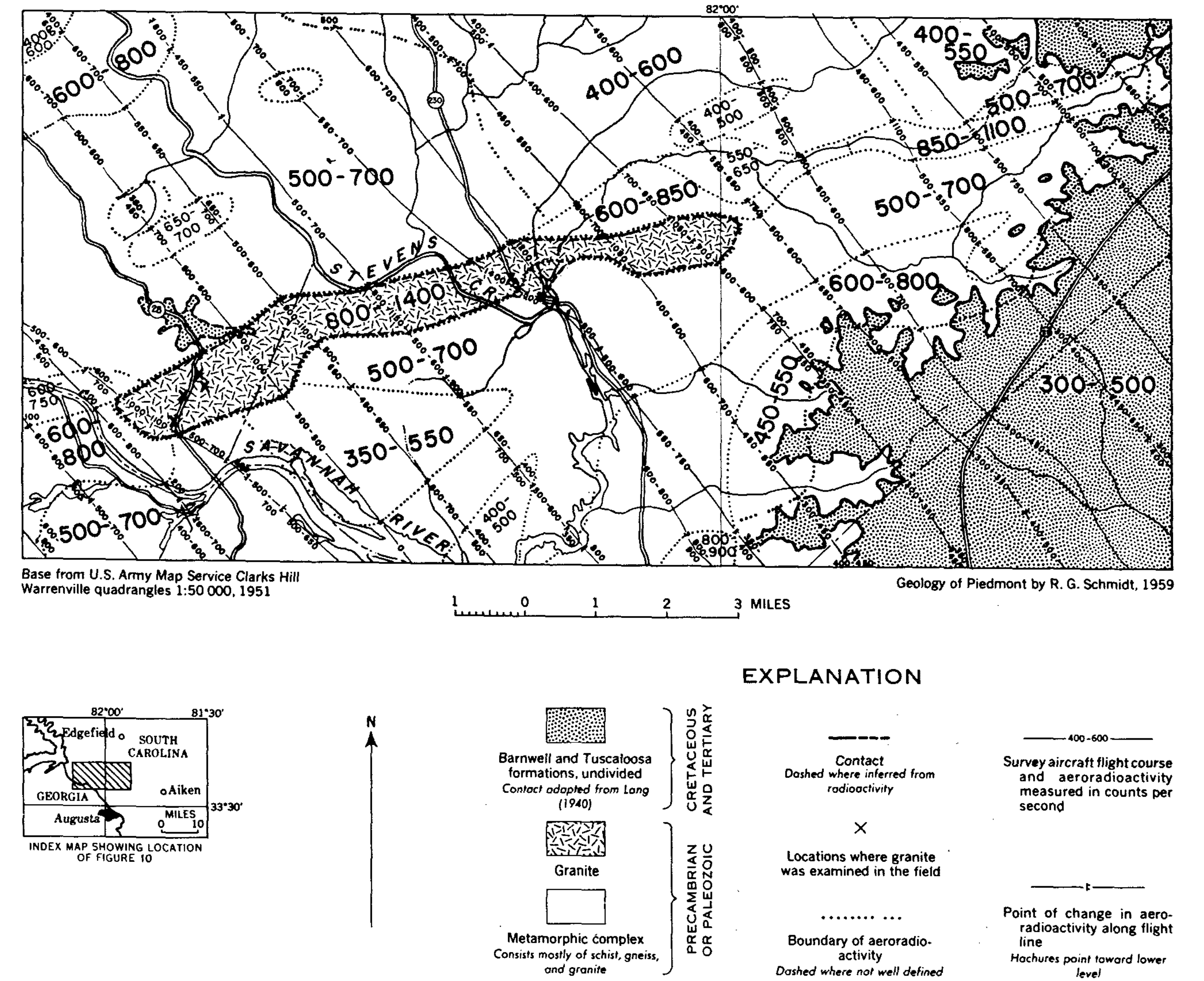


Fig. 10—Provisional geologic and aeroradioactivity map of an area in the Clarks Hill and Warrenville quadrangles, South Carolina and Georgia.

Appling, Columbia County, Ga. (Fig. 6). The granite contains quartz, alkalic feldspar, and biotite, and many roughly euhedral orthoclase phenocrysts as much as 40 mm long. The larger phenocrysts have small patches of plagioclase at their margins. Fresh outcrops of this rock are abundant along State Highway 232 between Kiokee Creek and Little Kiokee Creek. The area of high radioactivity seems to correspond to the area of the porphyritic granite at the places where the edges of the granite were mapped, and as a result the northern edge of the granite mass was drawn to correspond with the edge of the high radioactivity though no field observations were made there.

A very similar porphyritic granite occurs northwest of Batesburg in Saluda County, S. C. This granite is surrounded by other relatively radioactive rock--gneiss, schist, granite, and a radioactive facies of the Carolina slate belt--so that no contrast in radioactivity is found at the contacts. More granite of the same type occurs in Warren County, Ga., at Cedar Rock where a large quarry has been opened in it and extending southwestward to the Ogeechee River. Aeroradioactivity over part of the granite at Cedar Rock is as much as 1050 cps.

Along the Fall Line, Piedmont rocks are exposed downstream along valleys and also exposed in several valley bottoms entirely surrounded by Coastal Plain sedimentary rocks. In these marginal Piedmont rock exposures, the contact with the surrounding Coastal Plain formations is generally markedly reflected in the radioactivity survey if the Piedmont rock is schist, gneiss, or granite, but little or no radioactivity contrast is found at the contact if the Piedmont rock is that of the Carolina slate belt. Also, it was found that the most radioactive parts of the Coastal Plain occurring locally in South Carolina, especially certain gravelly layers near the base of the Tuscaloosa formation, are as radioactive as most of the granites and the metamorphic complex. Examples of this were observed near McTier Creek in northern Aiken County, S. C., where H. S. Johnson, Jr., (Division of Geology, South Carolina State Development Board) showed the writer highly radioactive gravelly sand at the base of the Tuscaloosa formation resting on a radioactive granite. The sand of this locality was considerably more radioactive than the underlying granite. The small angular pebbles at the base of the Tuscaloosa are similar to a blue-gray type of quartz that is very abundant in veinlets in the underlying granite. The angularity of the quartz fragments and their similarity to the quartz in the granite suggests that the pebbles were locally derived.

6.2 Distribution of Radioactivity Relative to Geology in the Coastal Plain

The aeroradioactivity of the Coastal Plain ranges from high--as much as 1300 cps--in Lexington County, S. C., in the northeast part of the area, to about 150 cps in the southern part of the area, far out on the Coastal Plain. In a very general way the distribution of radioactivity corresponds to the age of the sedimentary formations, but this correspondence could not be thoroughly checked because too little is known about the areal distribution of the Coastal Plain formations.

The area believed to be underlain by the Tuscaloosa formation in Lexington and eastern Aiken Counties, S. C., includes the most radioactive part of the Coastal Plain in the Savannah River Plant area. The formation is thin in this area, and it pinches out near the Edgefield and Saluda County lines. The radioactive layers seem to occur at different positions throughout the thickness of the formation. A similar occurrence of a radioactive basal gravelly part of the Tuscaloosa formation resting on granite similar to that at McTier Creek was found on Long Creek, a tributary of Twelvemile Creek in Lexington County. Other radioactive zones occur higher in the formation and radioactive gravel layers found on the east bank of the North Fork of the Edisto River (along State Highway 215, southwest of Pelion in Lexington County, S. C.) are probably very close to the top of the formation. The generally higher radioactivity of the Tuscaloosa formation in Lexington and eastern Aiken Counties is further substantiated by the samples described by Dryden[19].

In contrast to the area described above, the Tuscaloosa formation exposed in western Aiken County, S. C., and in Georgia is much less radioactive, generally ranging from 400 to 700 cps, though some local areas are higher or lower.

The extensive heavy mineral placer on Horse Creek in Aiken County, S. C., occurs in a valley eroded in the Tuscaloosa and younger formations. The heads of the main valley above Graniteville and of the tributary, Little Horse Creek are cut slightly into the underlying Piedmont rocks, and although these Piedmont rocks are radioactive and probably monazite bearing, the relative volume eroded is small and it seems more reasonable that the bulk of the heavy minerals in the placer came from concentration of the small amounts present in the Coastal Plain formations, especially the Tuscaloosa formation.

The monazite known to be present in the Horse Creek placer did not cause an increase in aeroradioactivity over this area, and it is reasoned that the radioactive material in the placer is effectively shielded by overlying alluvium and water. The heavy minerals, including monazite, are probably present in the deeper part of the placer and the placers generally occur in partly swampy flood plains.

In the lower Coastal Plain the range in radioactivity is 150 to 700 cps, and most of the area is between 300 and 600 cps. Most areas of similar radioactivity are large and irregular, and many of the changes are gradual and difficult to show as distinct lines. Some swamps form areas of distinctly low radioactivity and many river flood plains are distinctly higher or lower than the surrounding Coastal Plain. Parts of the Ogeechee River (Ga.), Savannah River and Edisto River (S. C.) flood plains are more radioactive than the adjacent formations where the rivers traverse the formations of Oligocene, Miocene, and Pleistocene ages, even though the flood plains are partly swampy (Fig. 11). These river systems are long and have their head-

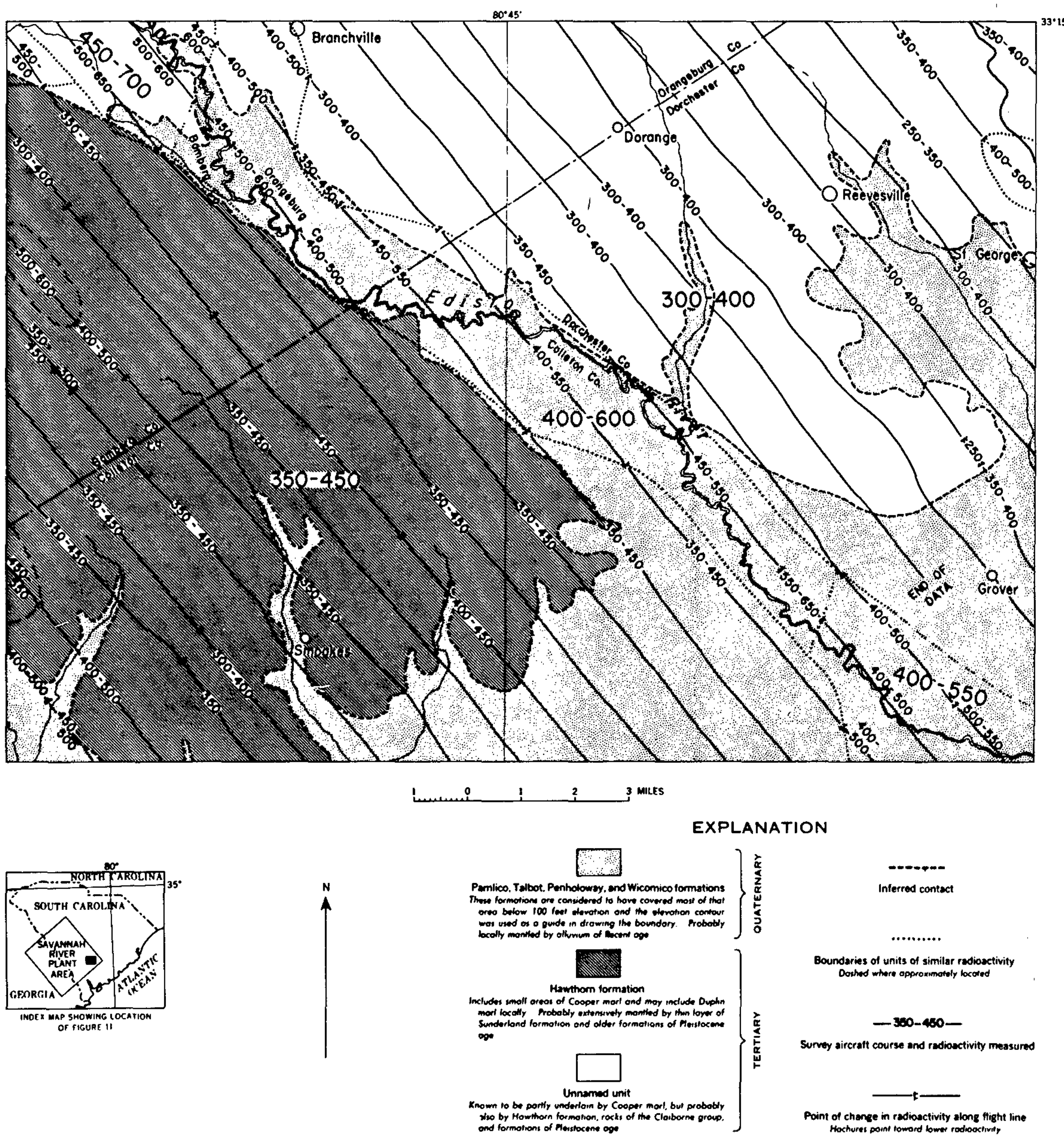


Fig. 11—Radioactivity and provisional geologic map of an area near Branchville, South Carolina.

waters in the Piedmont and older Coastal Plain formations. The rivers have transported radioactive material from the headwater areas and deposited it on flood plains in the flat Coastal Plain. In contrast, the Salkehatchie and Little Salkehatchie Rivers in South Carolina drain basins developed mostly in the Hawthorn formation and Pleistocene terrace formations. The flood plains of these rivers are generally about as radioactive as the adjacent upland, but in several places the flood plains are slightly less radioactive. This is particularly noticeable along the Coosawhatchie, a smaller river in Hampton County, S. C.

The Hawthorn formation is well known for the abundance of uraniferous phosphatic material in part of its thickness. Gamma-ray logs of drill holes in the formation show characteristic radioactive zones (G. E. Siple, U. S. Geological Survey, oral communication), and several anomalously radioactive areas probably related to the phosphatic materials were detected in an aeroradioactivity survey of the Edisto Island area, S. C.[20]. The aeroradioactivity measured over the Hawthorn formation in the Savannah River Plant area, however, is uniformly low. It can be speculated that the surface exposures of the Hawthorn formation in the Savannah River Plant area are only weakly radioactive because the uranium has been leached from the surficial layers.

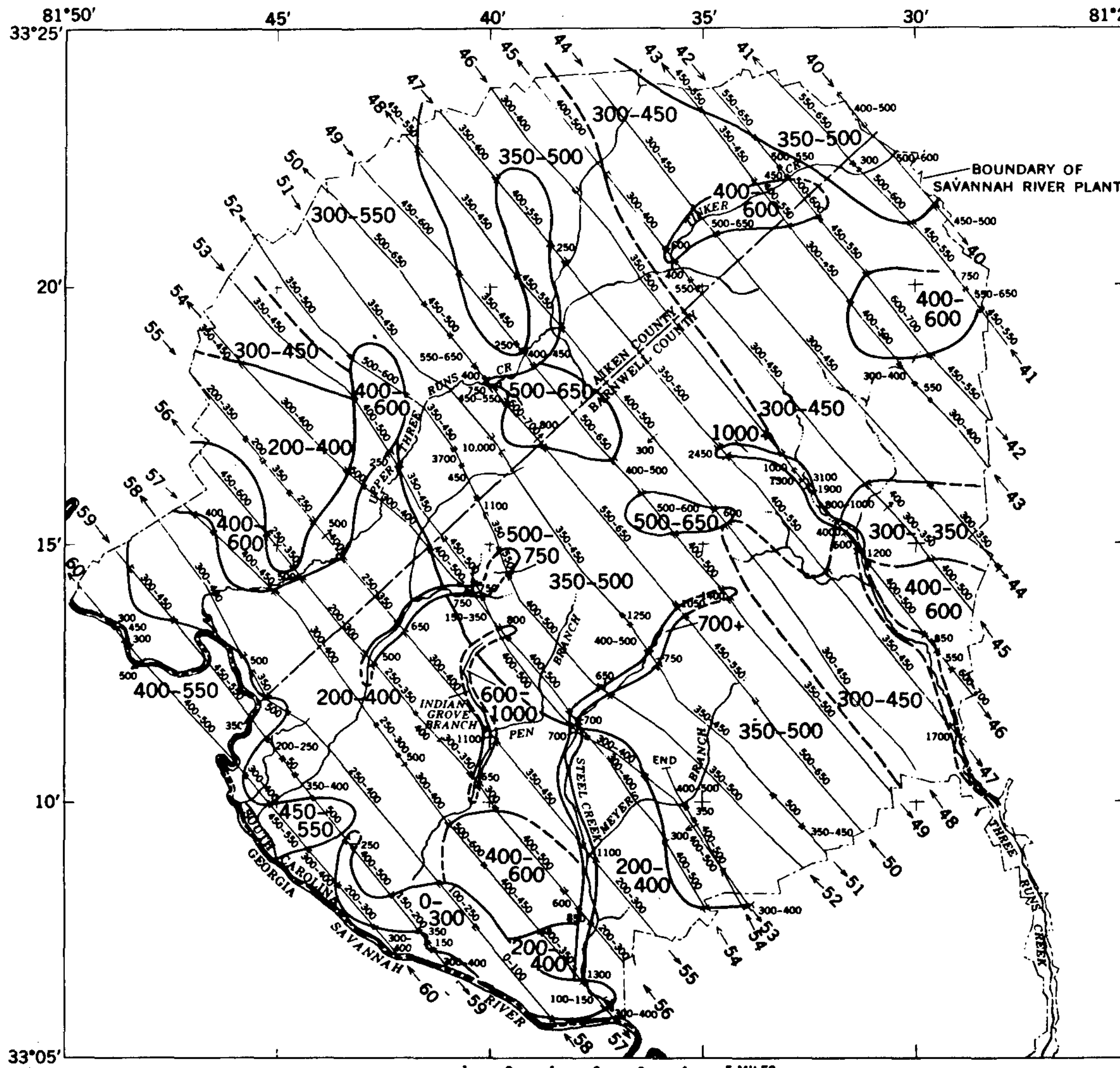
6.3 Detailed Aeroradioactivity of the Savannah River Plant

Fig. 12 shows the detailed gamma aeroradioactivity of the Savannah River Plant. Some of the aeroradioactivity levels (maximum of 10,000 cps) shown on Fig. 12 are higher than the generally low levels (200 to 650 cps) related to natural phenomena. These higher readings result from normal atomic energy operations at the Savannah River facility and the fact that the U. S. Geological Survey airborne radioactivity equipment (instrumentation) is extremely sensitive to small changes in radiation levels.

Information on radioactivity levels in the environs and outside the plant boundaries of Atomic Energy Commission and contractor installations are reported in special periodic reports from each installation. These reports are 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.

7. SUMMARY

The gamma aeroradioactivity of the Savannah River Plant area has a wide range, from 150 to 2100 cps. Field examination and comparison with geologic maps indicate that the radiation level is closely related to the type of soil or rock occurring at the surface. The association of radioactivity levels with rock types is locally so good that geologic contacts may be reasonably approximated from



Base from U.S. Atomic Energy Commission topographic map of the Savannah River Plant, South Carolina, 1:48,000, 1957

EXPLANATION

300-450

Boundary of aeroradioactivity units

Dashed where approximately located. Numbers indicate general gauge of radioactivity levels, in counts per second

400-500

Survey aircraft flight course and aeroradioactivity measured, in counts per second

Point of change in aeroradioactivity along flight line

Hachures point toward lower aeroradioactivity

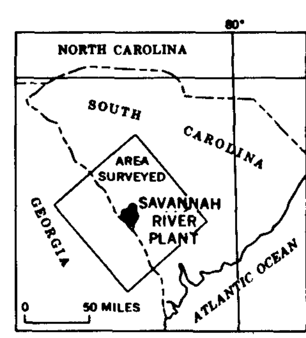
800

300

Location of narrow aeroradioactivity high or low along flight line

←56

Direction of flight and line number



INDEX MAP SHOWING LOCATION OF SAVANNAH RIVER PLANT

Fig. 12—Detailed aeroradioactivity of the Savannah River Plant.

changes in radiation level, even though the bedrock is mantled by thick residual soil. Within the Piedmont, the granites and part of the metamorphic complex have a high aeroradioactivity, the aeroradioactivity of the slate belt is generally low. In the Coastal Plain the aeroradioactivity of Upper Cretaceous and Eocene rocks ranges from moderate to high and that of the younger beds is generally low.

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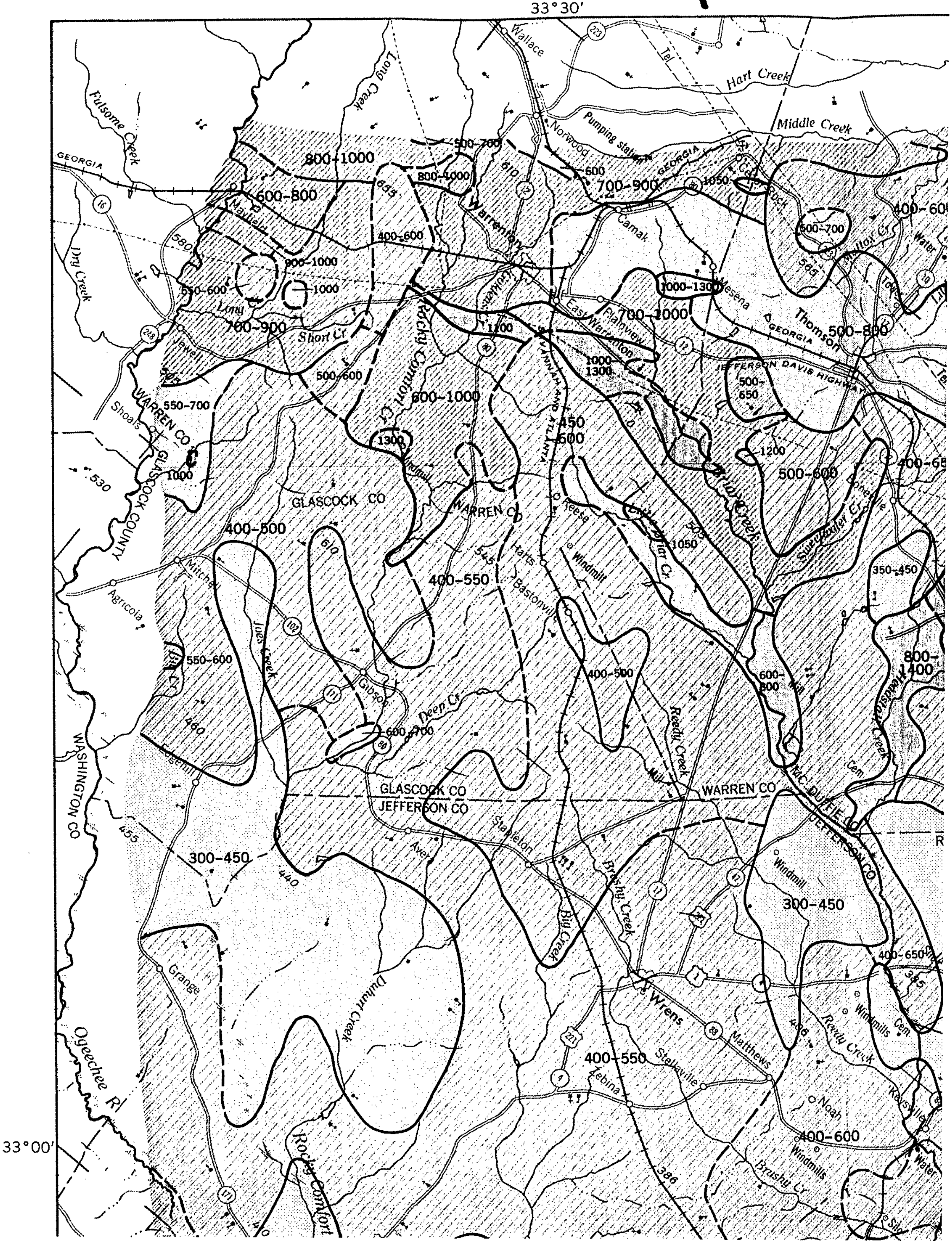

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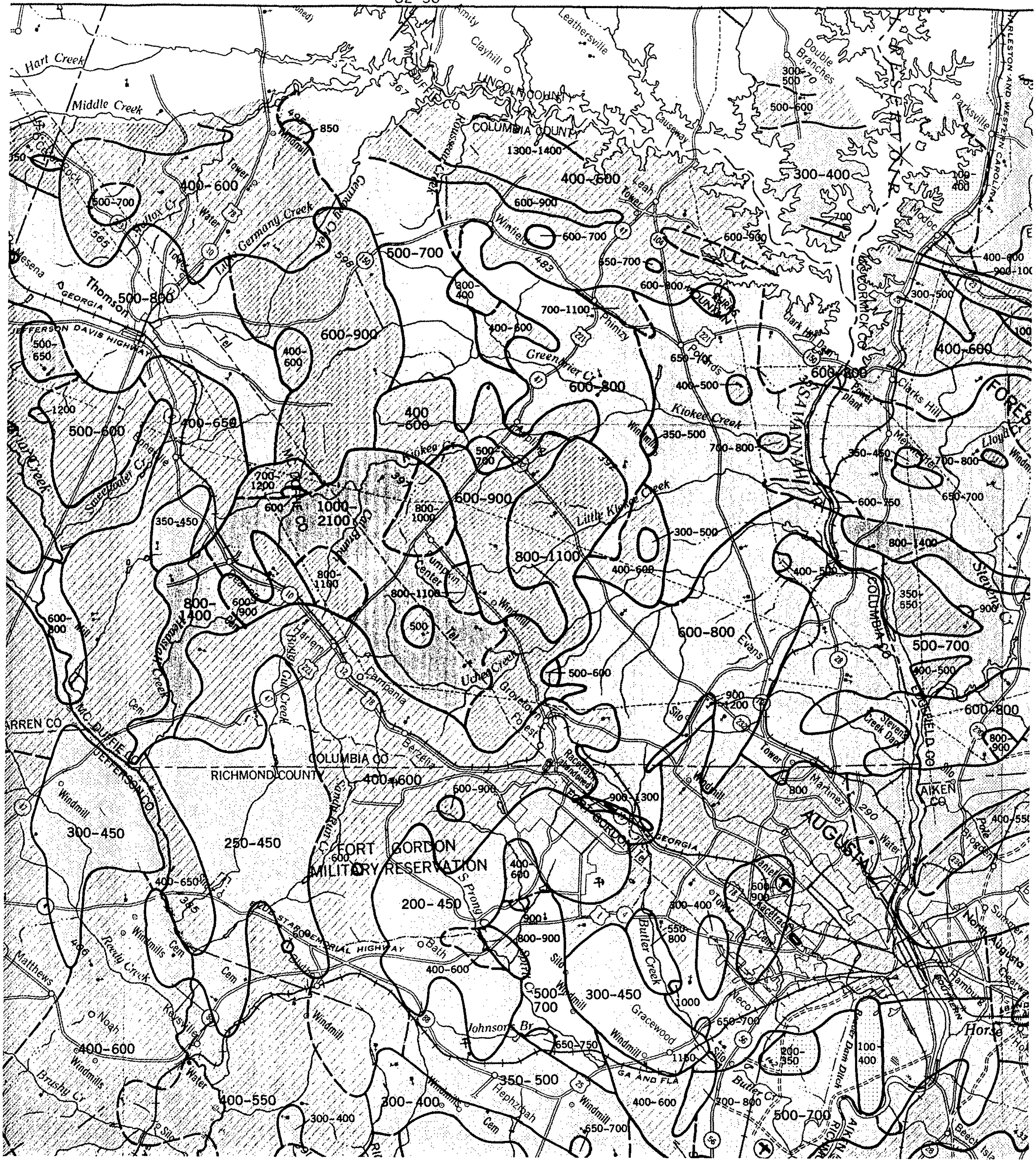

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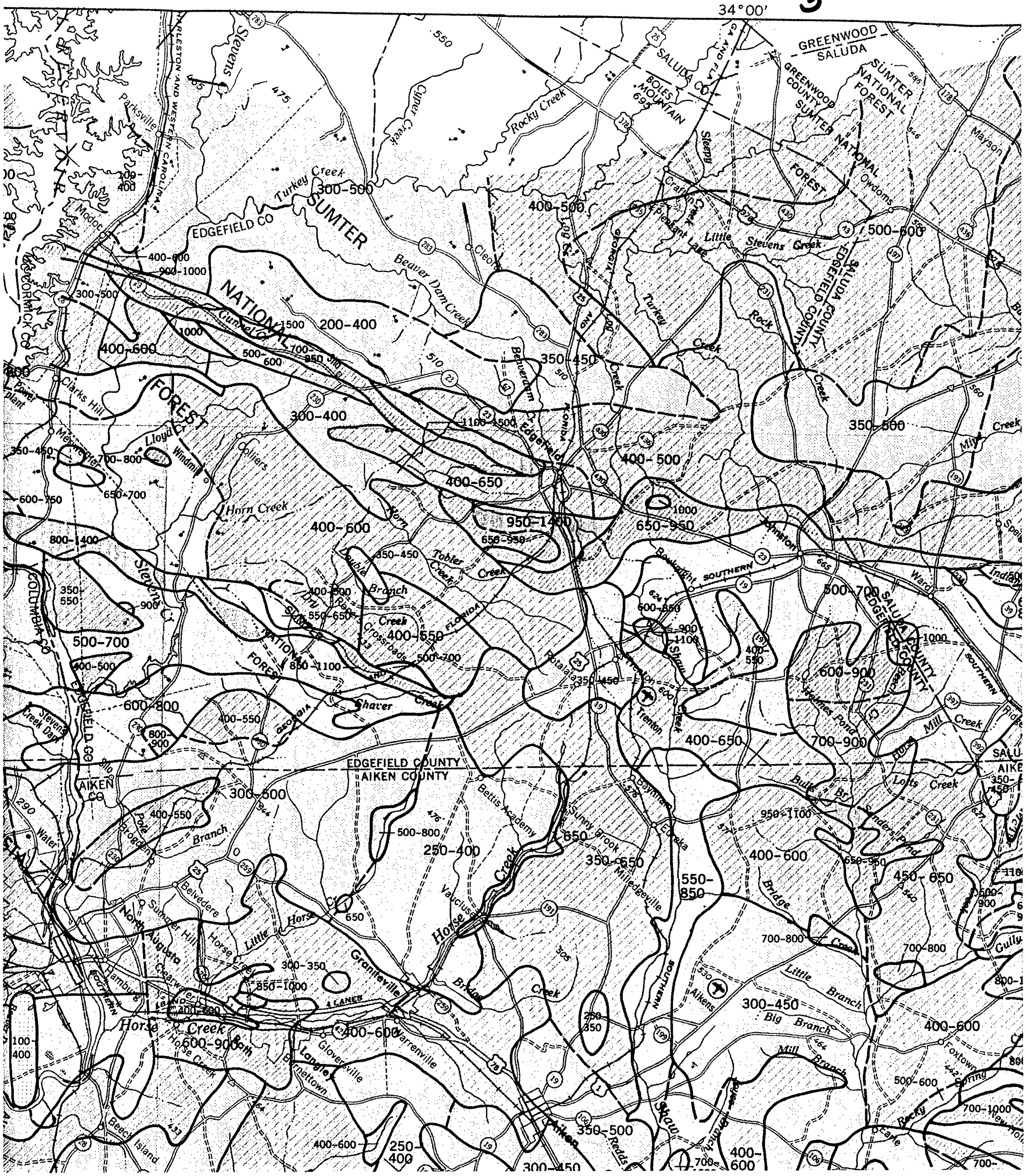

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GEOPHYSICAL INVEST
MAP GP-306

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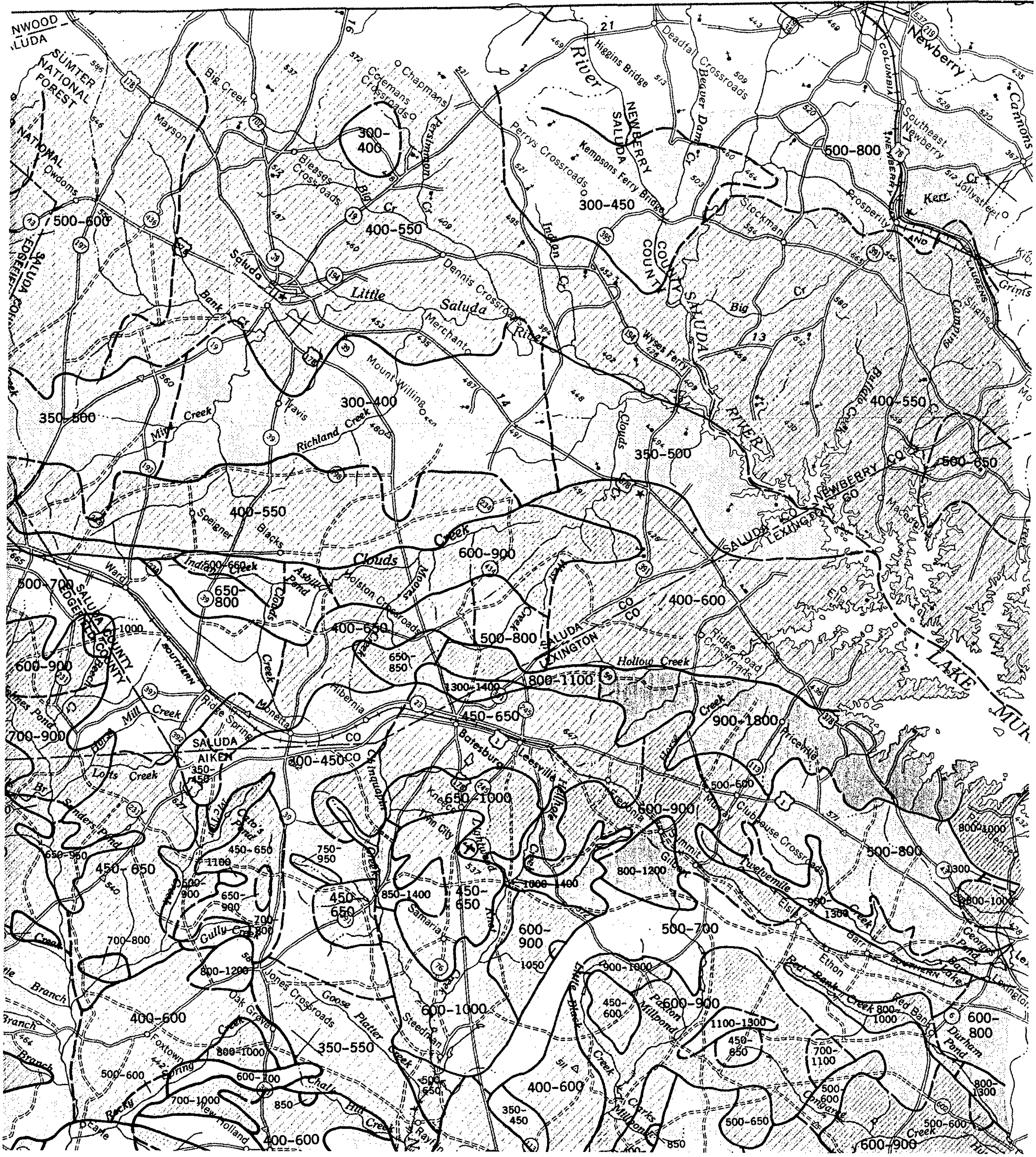

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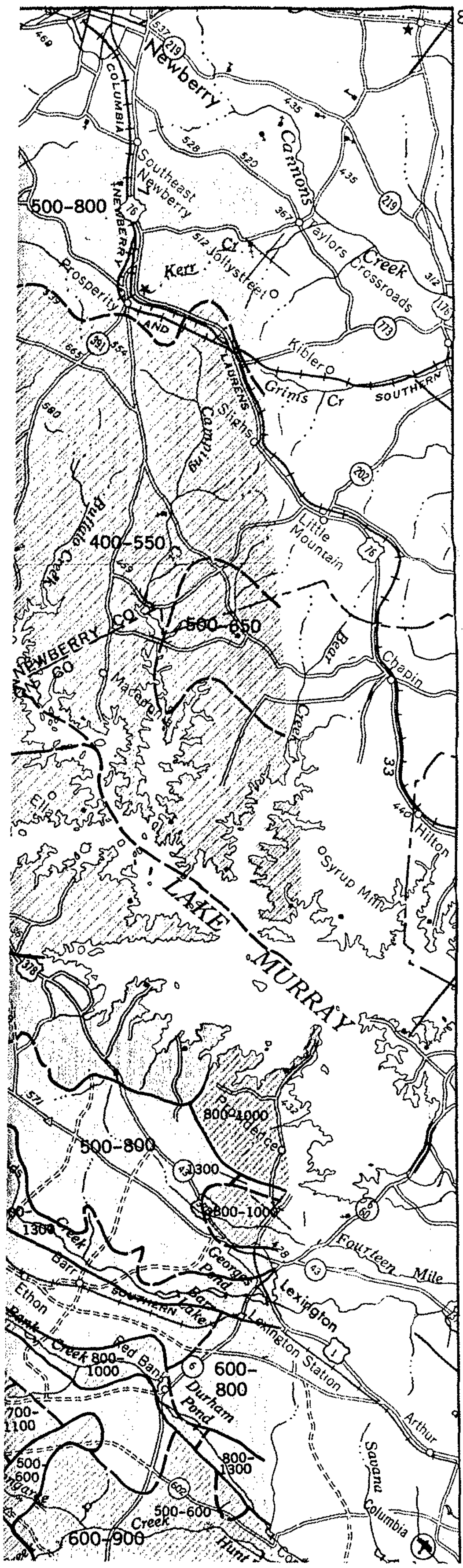
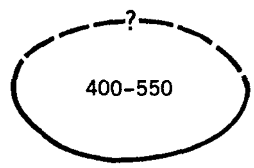
OPHYSICAL INVESTIGATIONS
MAP GP-306

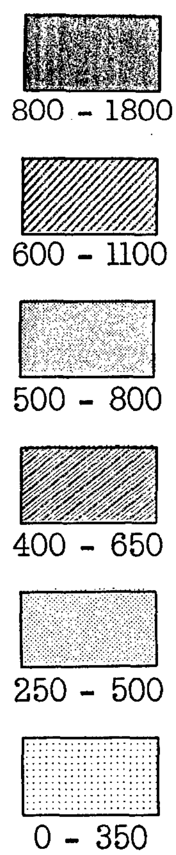
5



EXPLANATION

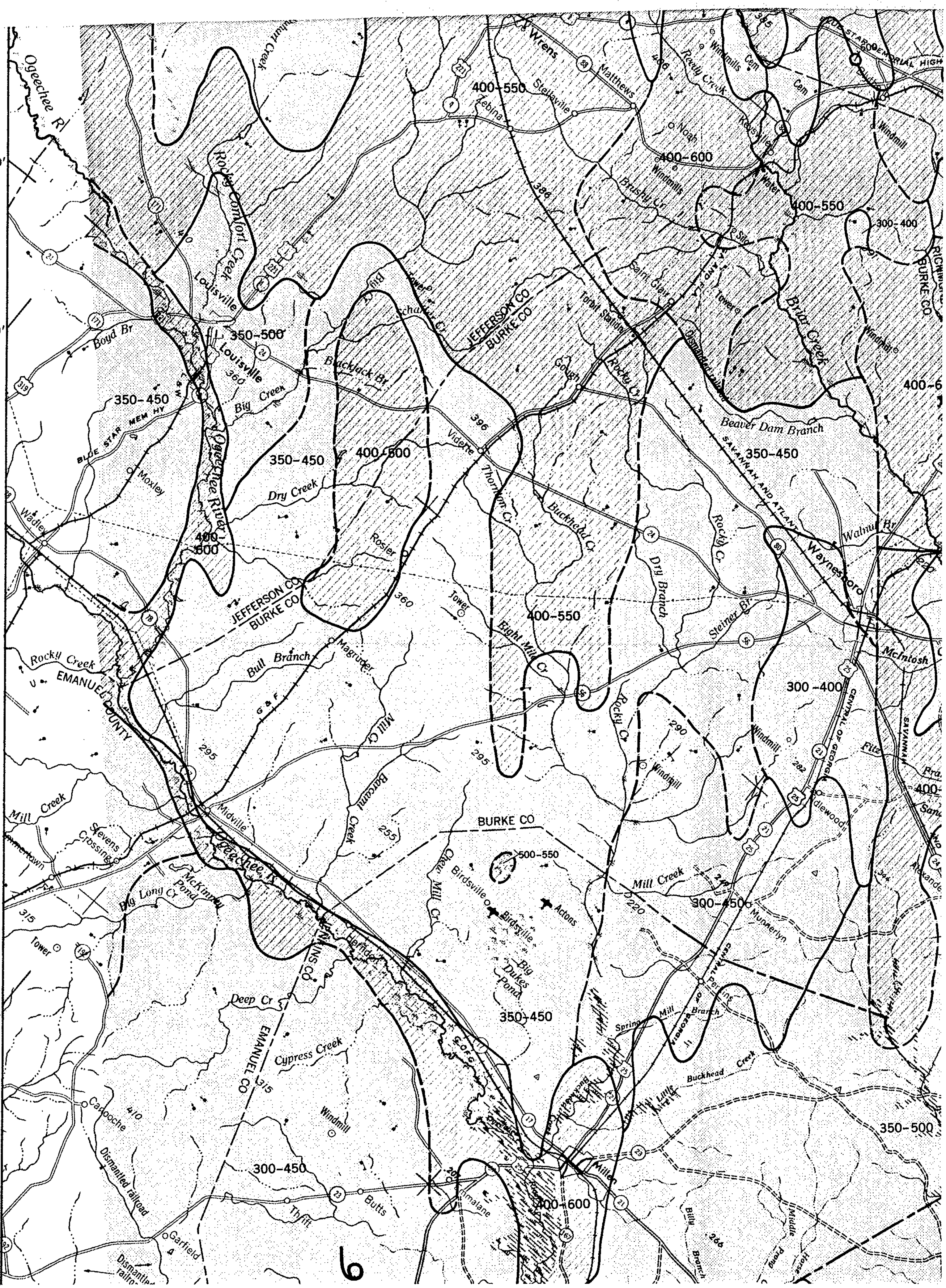


Radioactivity boundary
Solid where well defined, dashed where transitional, queried where not well defined. Numbers indicate general range of radioactivity levels in counts per second.

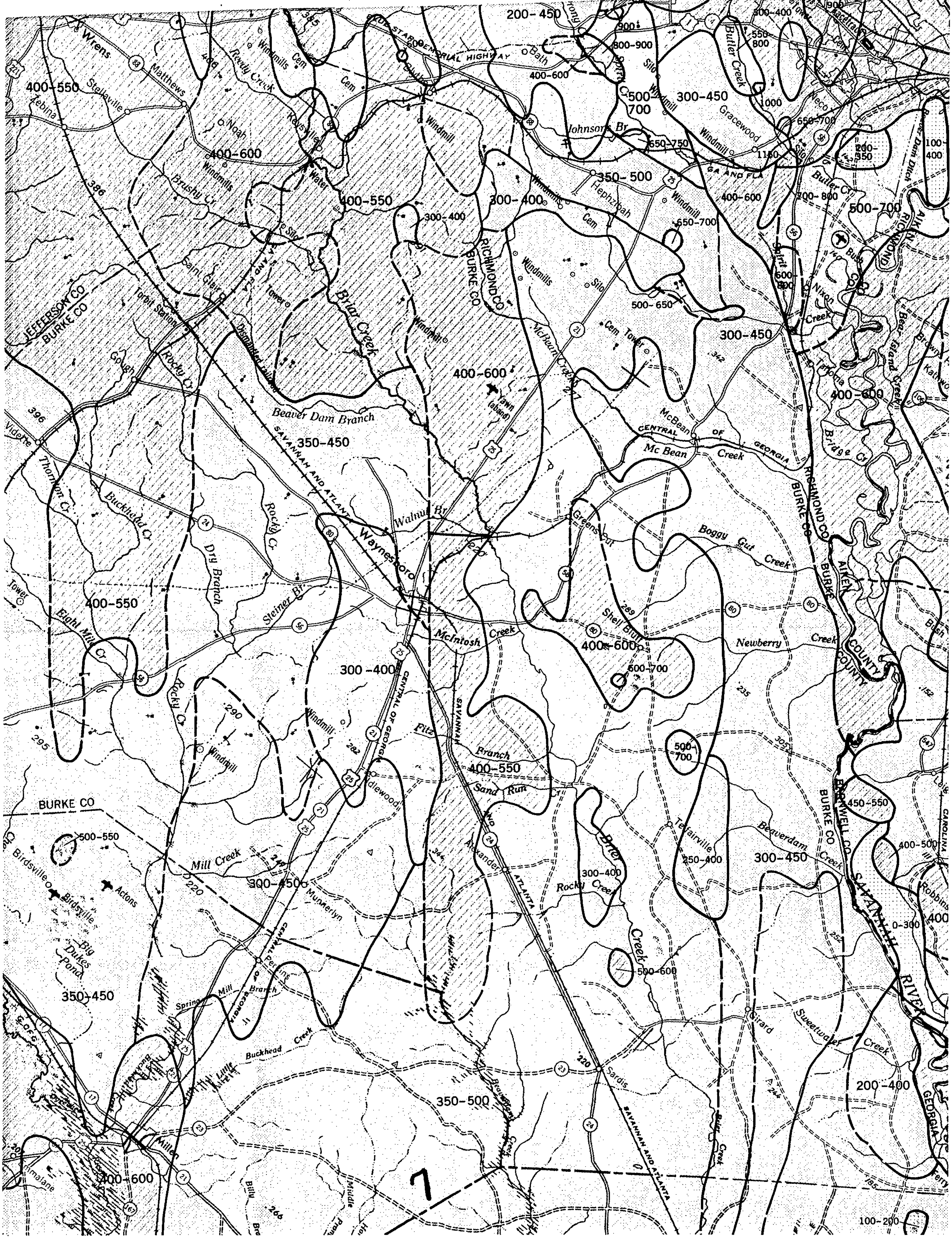


Approximate ranges of radioactivity

The survey was made with scintillation detection equipment (Davis and Reinhardt, 1957[1]) installed in a twin-engine aircraft. Par-

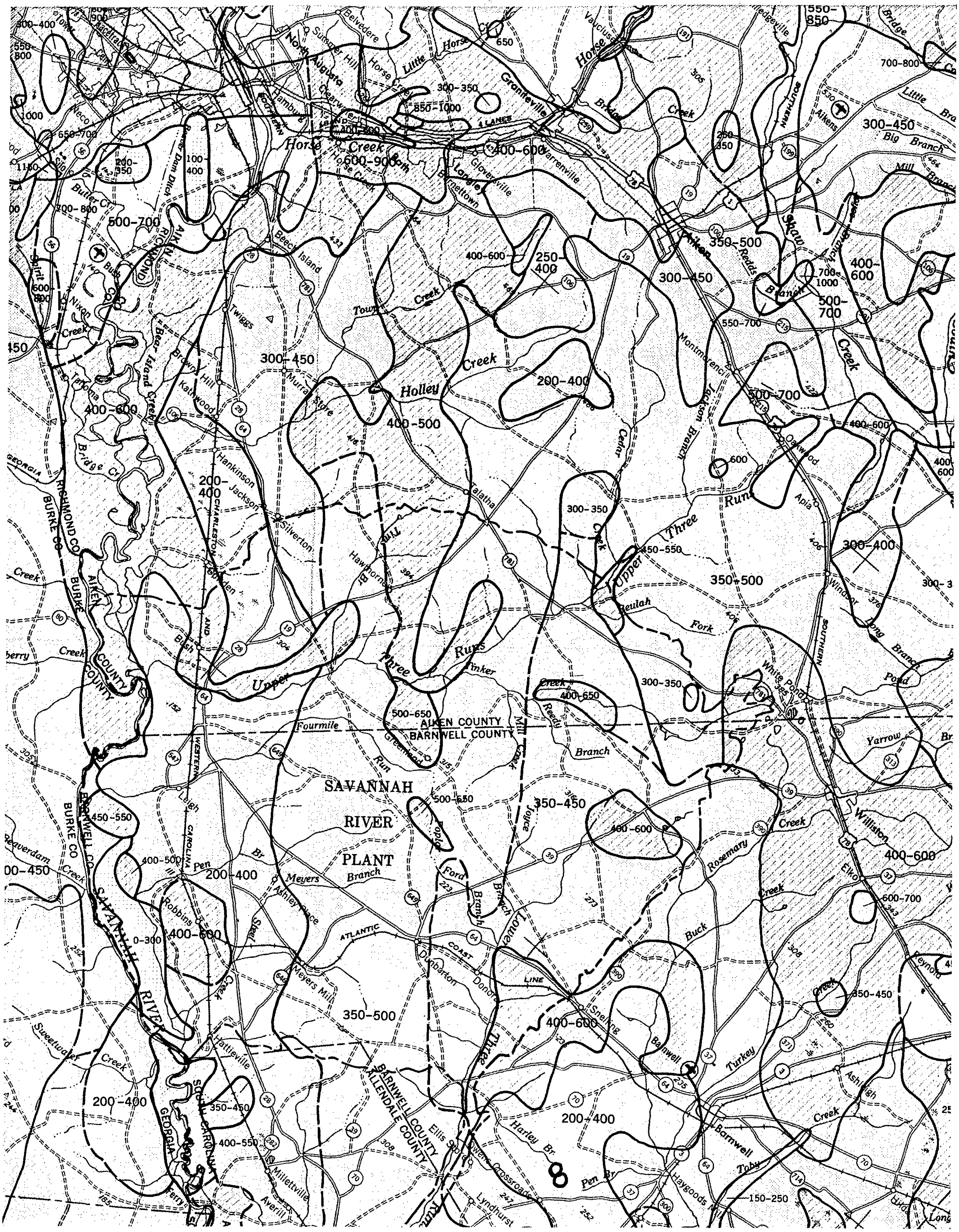


Ogeechee R
00′
30′
Wrens
Matthews
Stellaville
Zebina
400-550
Noah
400-600
Windmills
Brushy Cr
400-550
300-400
Rocky Comfort Creek
Louisville
350-500
Louisville
Boyd Br
350-450
Blue Star Mem Hy
Big Creek
Moxley
Ogeechee River
Wadley
400
500
Blackjack Br
JEFFERSON CO
BURKE CO
Gough
Rocky Cr
Briar Creek
BURKE CO
400-6
Beaver Dam Branch
Savannah and Atlantic
350-450
Vidette
Thorn Cr
Buckhead Cr
Dry Branch
Rocky Cr
350-450
400-500
Dry Creek
Rosier
Tower
Walnut Br
Waynesboro
JEFFERSON CO
BURKE CO
400-550
Steiner Br
Eight Mile Cr
McIntosh
Magruder
Bull Branch
Rocky Creek
EMANUEL COUNTY
Mill Cr
300-400
Central of Georgia
295
295
290
Windmill
Mill Creek
Stevens Crossing
Midville
Barcomb Creek
255
BURKE CO
500-550
Ogeechee R
McKinney Pond
Big Long Cr
315
Tower
Birdsville
Actons
Chew Mill Cr
Mill Creek
300-450
Munnerlyn
220
Big Dukes Pond
350-450
Deep Cr
Cypress Creek
EMANUEL CO
315
Spring Mill Branch
Perkins
Buckhead Creek
Little Buckhead
Windmill
Cadooche
410
Dismantled railroad
300-450
Butts
Thrift
Rimatane
400-600
Millen
350-500
Garfield
Dismantled railroad
Billy Branch
266
Middle Pond



Wrens
Matthews
Stellaville
Zebina
400-550
Noah
Reysville
400-600
Windmills
Brushy Cr
400-550
Briar Creek
300-400
RICHMOND CO
BURKE CO
JEFFERSON CO
BURKE CO
Saint Clair
Tarbit Station
Gough
Rocky Cr
Vidette
Thomas Cr
Buckhead Cr
Dry Branch
Rocky Cr
Beaver Dam Branch
SAVANNAH AND ATLANTA
350-450
400-600
Waynesboro
Walnut Br
Steiner Br
400-550
Eight Mile Cr
McIntosh Creek
300-400
Windmill
Fitz Branch
400-550
Sand Run Cr
Idlewood
BURKE CO
500-550
Birdsville
Actons
Big Dukes Pond
Mill Creek
300-450
Munnerlyn
Perkins
Spring Mill Branch
350-450
Buckhead Creek
350-500
Millen
400-600
Sardis
Girard
Sweetwater Creek
200-400
GEORGIA
100-200
Ferry
200-450
900
800-900
400-600
500-700
300-450
Johnsons Br
650-750
Hephzibah
350-500
650-700
1160
Gracewood
Butler Creek
550-800
1000
Windmill
Silo
Cem
300-400
GA AND FLA
400-600
Butler Cr
200-800
500-700
200-350
100-400
AIKEN
RICHMOND
600-800
Nixon
Spirit Creek
McBean Creek
500-650
300-450
McBean
CENTRAL OF GEORGIA
Mc Bean Creek
400-600
Beaver Island Creek
Bridge Cr
RICHMOND CO
BURKE CO
Boggy Gut Creek
Greens Cut
Shell Bluff
400-600
600-700
Newberry Creek
AIKEN COUNTY
BURKE COUNTY
500-700
BARNWELL CO
BURKE CO
450-550
Telfairville
Beaverdam Creek
250-400
300-450
400-500
300-400
Rocky Creek
Brier Creek
500-600
SAVANNAH RIVER
CAROLINA
Robbins
0-300

7



North Augusta
Belvedere
Sumter Hill
Clearwater
Hamburg
Horse Creek
Little Horse Creek
Graniteville
Vaucluse
Horse Creek
Bridge Creek
Warrenville
Gloverville
Langley
Burnettown
Beech Island
Twiggs
Brown Hill
Kathwood
Bear Island Creek
Murray Store
Town Creek
Holley Creek
Hankinson
Jackson
Silverton
Talatha
Hawthorne
Tims Br
Upper Three Runs
Beulah
Cedar Creek
Montmorenci
Jackson Branch
Oakwood
Apia
Windsor
White Pond
Williston
Elko
Aiken
Aikens
Shaw Creek
Reeds Branch
Big Branch
Mill Branch
Little Bridge
Long Branch
Yarrow
Ellenton
Fourmile
Greenwood
Run
Tinker Creek
Reedy Branch
Mill Creek
Joyce Branch
AIKEN COUNTY
BARNWELL COUNTY
SAVANNAH RIVER PLANT
Meyers Branch
Ashley Place
Meyers Mill
Ford Branch
Dunbarton
Donora
Lower Three Runs
Snelling
Barnwell
Rosemary Creek
Buck Creek
Turkey Creek
Toby Creek
Ashleigh
Harley Br
Pen Br
Haygoods
Ellis Store
Owens Crossroads
Lyndhurst
Millettville
Averill
Hattieville
Robbins
Pen Br
Leigh
Steel Creek
Sweetwater Creek
Beaverdam Creek
SAVANNAH RIVER
SOUTH CAROLINA
GEORGIA
RICHMOND CO
BURKE CO
AIKEN COUNTY
BURKE COUNTY
BARNWELL CO
BURKE CO
BARNWELL COUNTY
ALLENDALE COUNTY
Butler Cr
Spirit Creek
Nixon Creek
Bush
Tarbora
Bridge Cr
Upper
Three
Runs
Fork
ATLANTIC COAST LINE
CHARLESTON AND WESTERN CAROLINA
SOUTHERN
300-400
550-800
1000
650-700
1150
200-350
100-400
200-800
500-700
600-800
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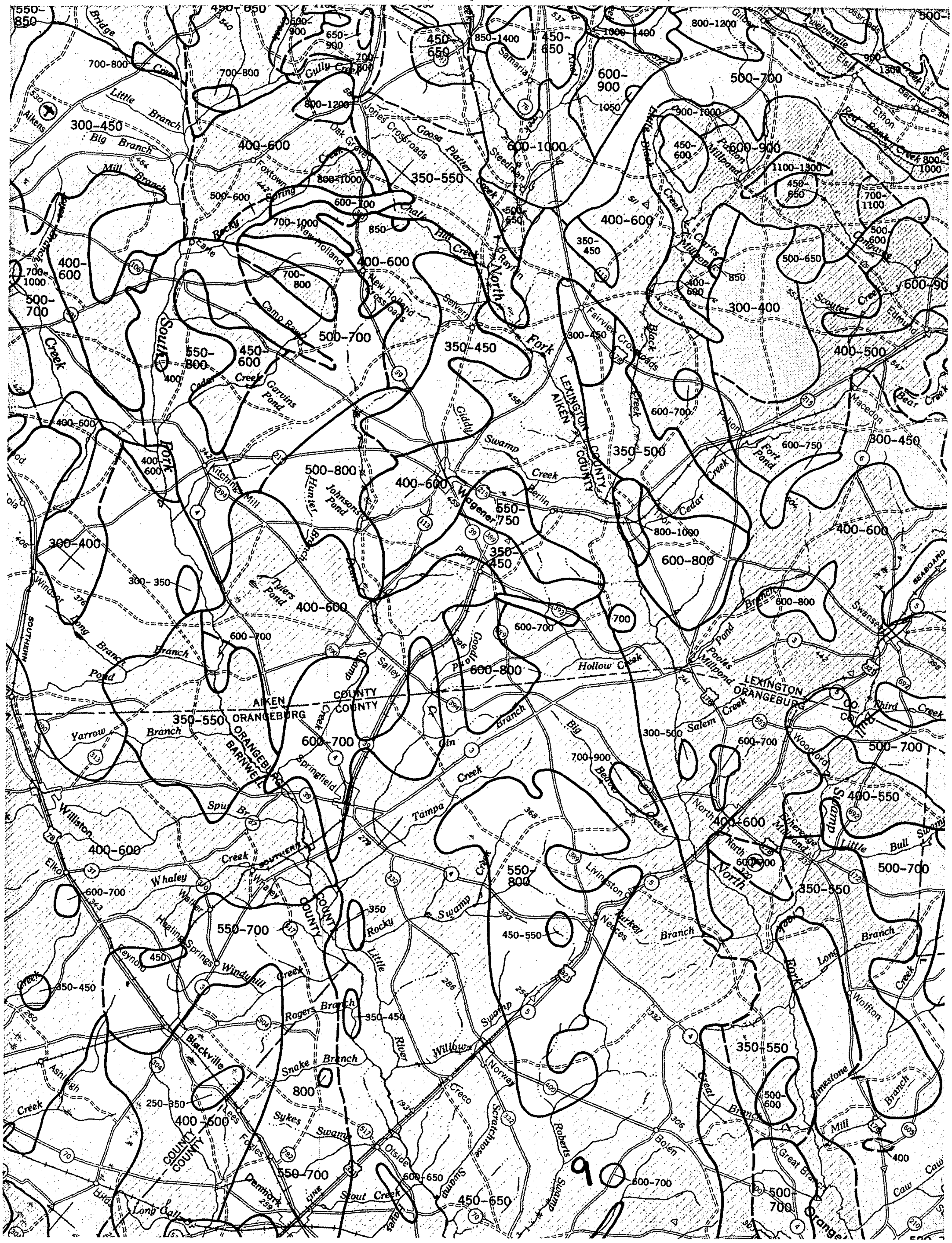
150-250
400-600



LEXINGTON COUNTY
AIKEN COUNTY
AIKEN COUNTY
ORANGEBURG COUNTY
ORANGEBURG
BARNWELL
LEXINGTON
ORANGEBURG
Aikens
Big Branch
Mill Branch
Little Branch
Bridge Creek
Gully Creek
Foxtown
Oak Grove
Jones Crossroads
Goose
Platter
Samaria
Steedman
Rocky
Spring
New Holland
New Holland Crossroads
Chalk Hill Creek
Rayfin
North Fork
South Fork
Camp Branch
Cedar Creek
Garvins Pond
Selvern
Giddy Swamp
Kitchings Mill
Johnsons Pond
Hunter
Wagener
Berlin
Fairview Crossroads
Black Creek
Clarks Millpond
Peapon Millpond
Scouter Creek
Edmund
Ethon
Red Bank Creek
Twelvemile Creek
Elsie
Congaree
Macedon
Bear Creek
Fort Pond
Pelion
Cedar Creek
Swansea
Tylers Pond
Windsor
Long Branch
Branch
Pond
Salley
Goodland
Hollow Creek
Pooles Millpond
Salem
Woodford
Yarrow
Branch
Springfield
Gin
Tampa
Creek
Big Beaver Creek
North Fork
Williston
Elko
Whaley
Creek
Healing Springs
Reynold
Windy Hill Creek
Rocky
Swamp
Little River
Rogers Branch
Snake Branch
Blackville
Willow
Swamp
Norway
Livingston
Neeses
Turkey Branch
Creco
Sykes Swamp
Lees
Denmark
Long Gall
Stout Creek
Scratchnose
Roberts
Bolen
Great Branch
Limestone Branch
Mill
Long Branch
Wolfton
Little Bull Swamp
Great Branch
Third Creek
SOUTHERN
SEABOARD
550-850
450-650
700-800
700-800
650-900
500-900
800-1200
450-650
850-1400
450-650
1000-1400
800-1200
500-700
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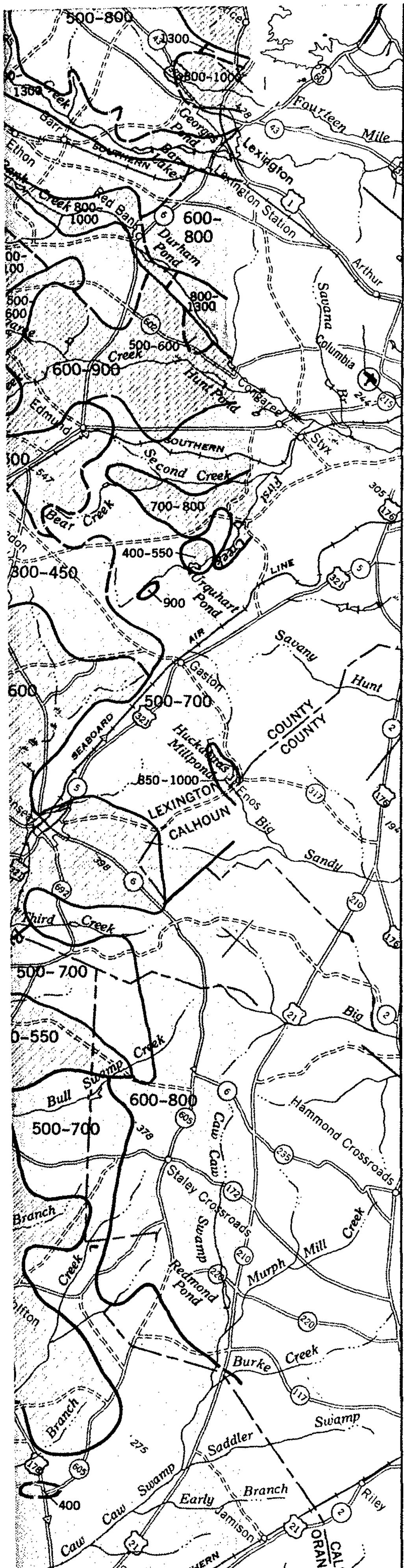
600-700
500-700
400
9



34°00′

81°00′

0 - 350

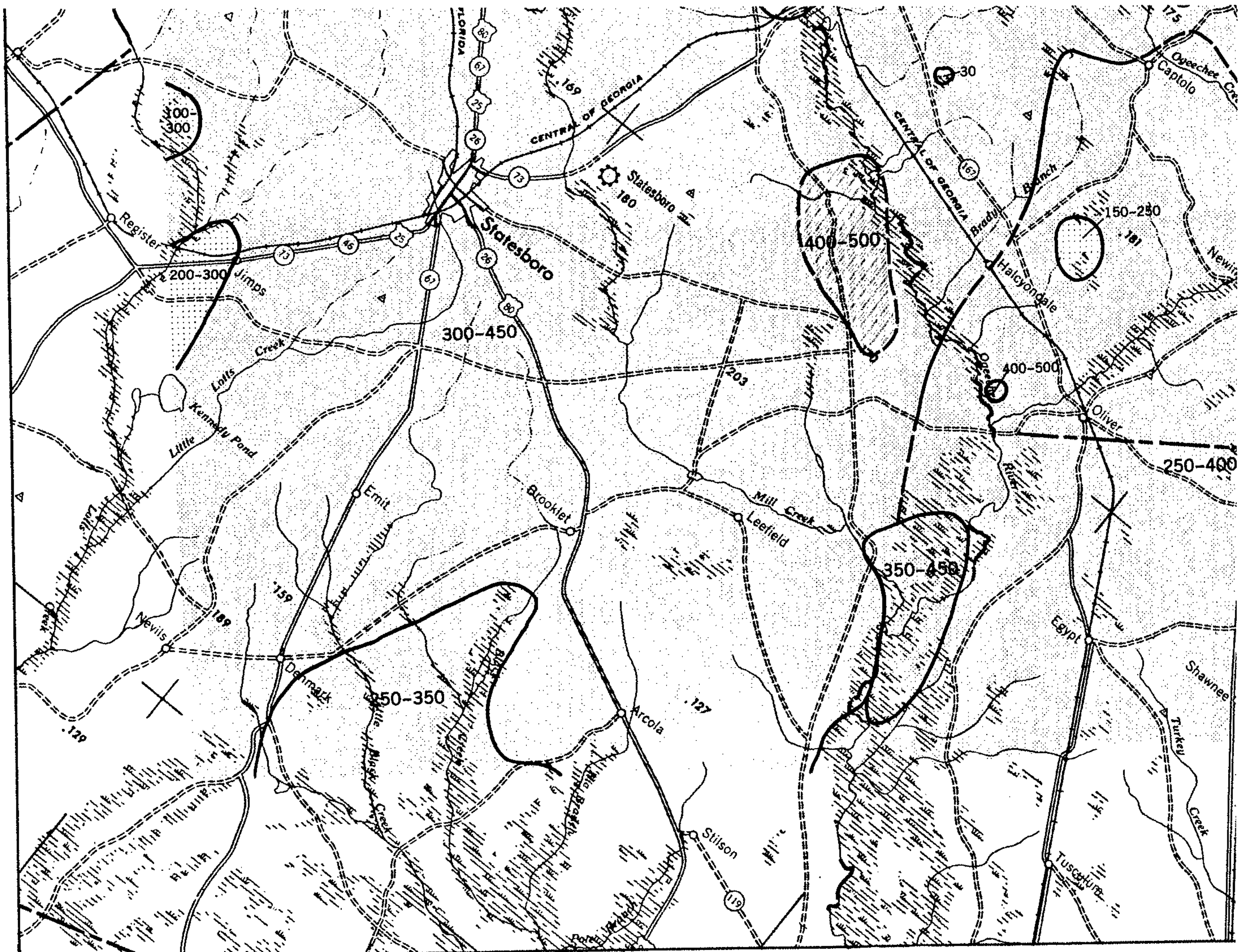
Approximate ranges of radioactivity

The survey was made with scintillation detection equipment (Davis and Reinhardt, 1957[1]) installed in a twin-engine aircraft. Parallel northwest-southeast flight traverses spaced at one-mile intervals were flown at a nominal elevation of 500 feet above the ground. The flight path of the aircraft was recorded by a gyrostabilized continuous-strip-film camera. The radioactivity data were compensated for deviations from the 500-foot surveying elevation, and for the cosmic-ray component.

The effective area of response of the scintillation equipment at an elevation of 500 feet is approximately 1,000 feet in diameter, and the radiation recorded is an average of the radiation received from within the area. The scintillation equipment accepts only pulses originating from gamma radiation with energies greater than 50 kev (thousand electron volts). A cesium-137 source is used during periodic calibrations to assure uniformity of equipment response.

A 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 is determined twice daily by calibrations at 2,000 feet above the ground, and is removed from the radiation data.

The component due to radionuclides in the air at 500 feet above the ground 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 affect discrimination of the radioactivity levels that reflect changes in the ground



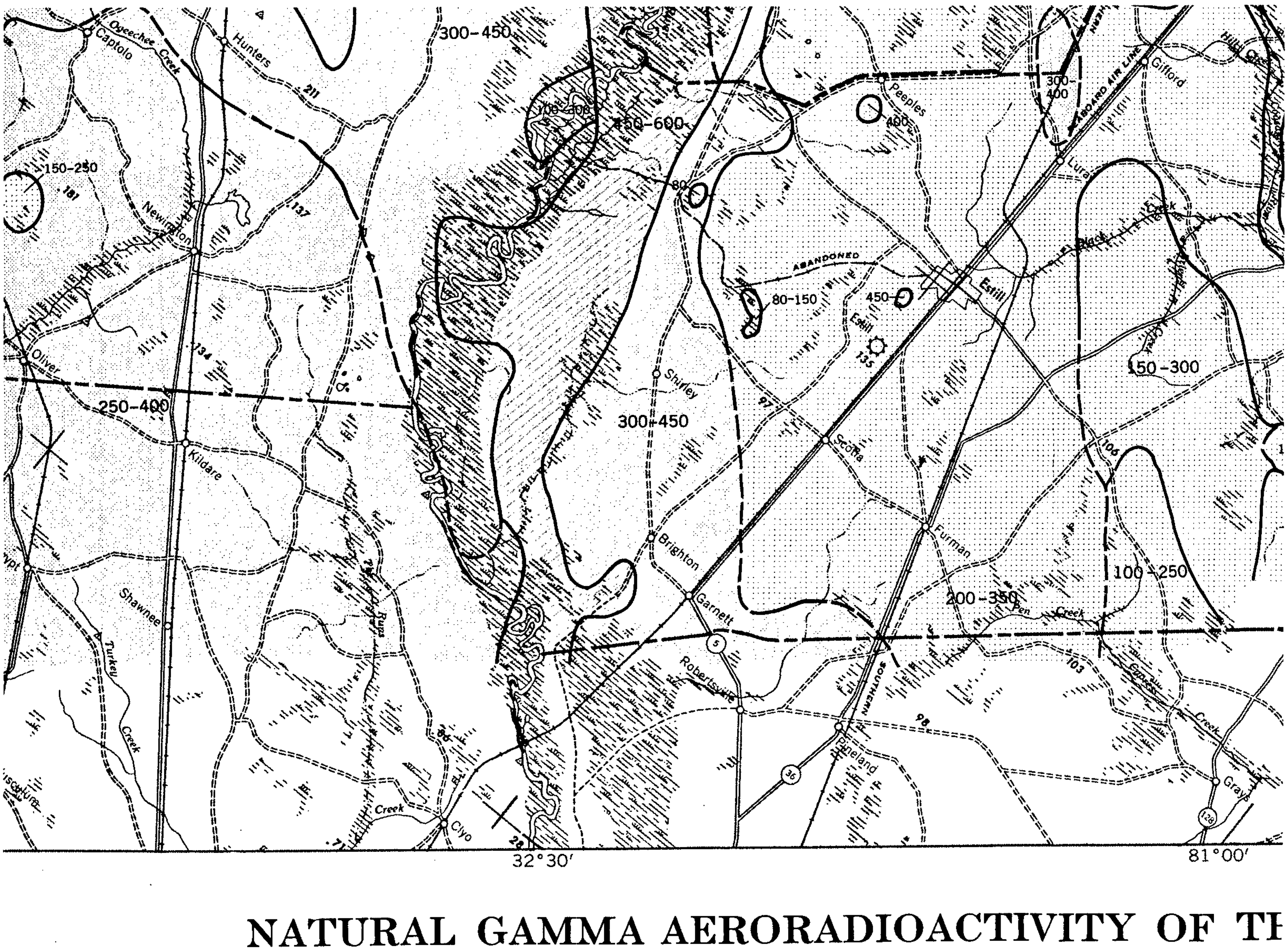
11

Base from Army Map Service, Corps of Engineers, 1:250 000-scale topographic map series, Athens, Augusta, Macon, Savannah, Spartanburg sheets

TRUE NORTH

MAGNETIC NORTH DEVIATES FROM 1°15′ E TO 2° W WITHIN MAP AREA

AEC-CEX—58.4.2
GEOPHYSICAL INVESTIGATIONS
MAP GP-306



NATURAL GAMMA AERORADIOACTIVITY OF TH
SOUTH CAROLINA ANI

12

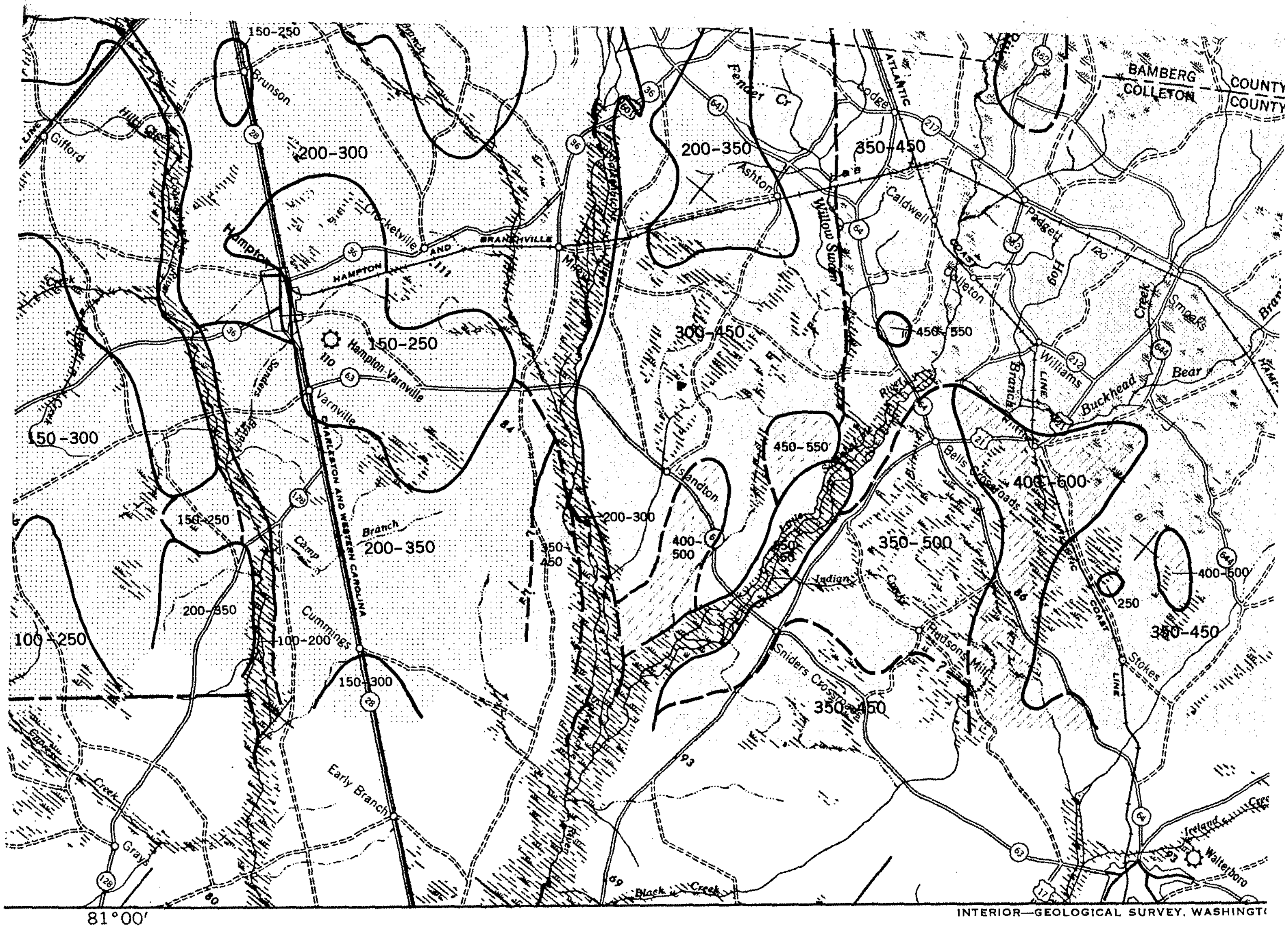
By

Robert G. Schmi

SCALE 1:250 000

4 2 0 4 8

1961



Y OF THE SAVANNAH RIVER PLANT AREA,
LINA AND GEORGIA

13

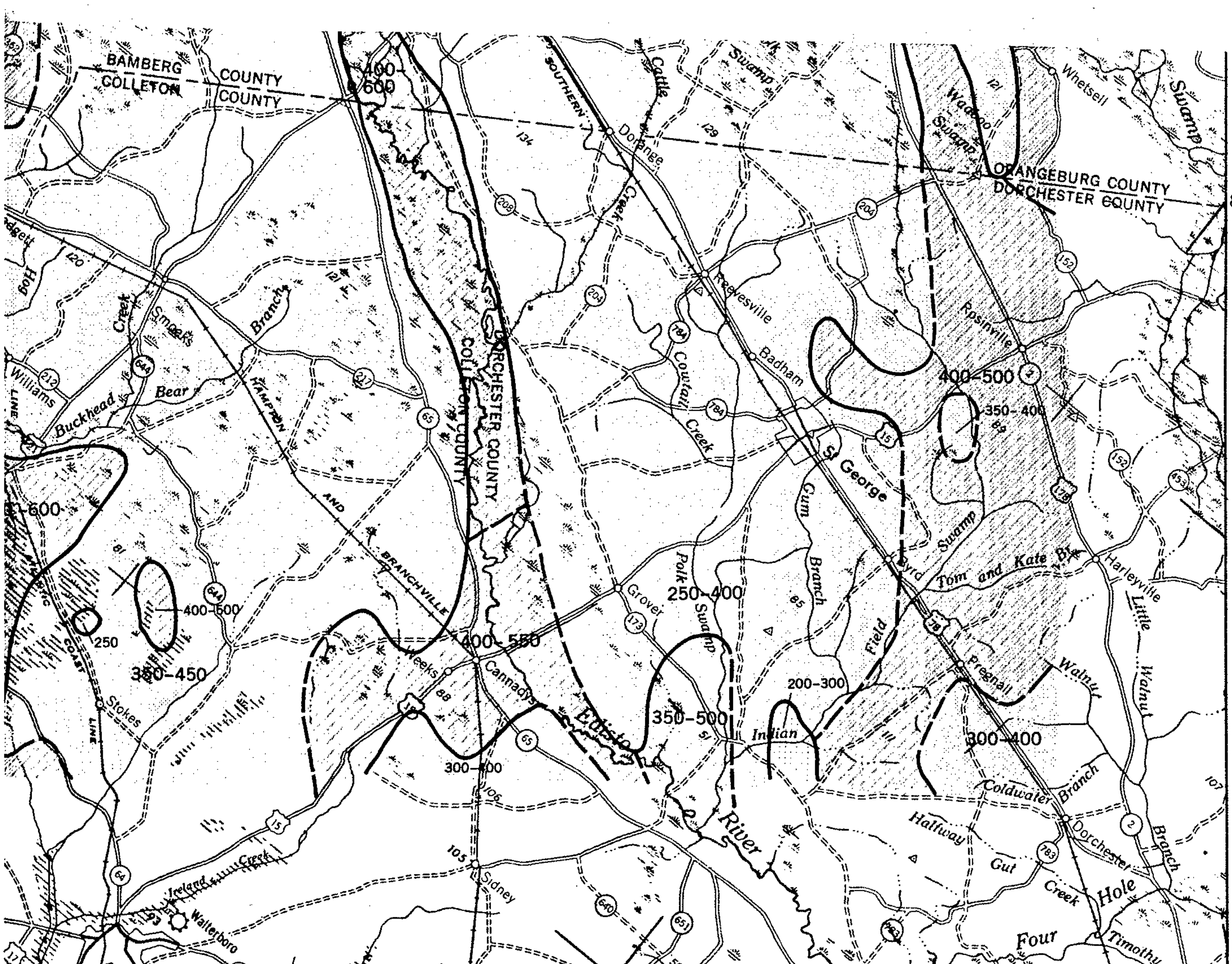
By

t G. Schmidt

ALE 1:250 000

8 12 16 20 MILES

1961



80°30′

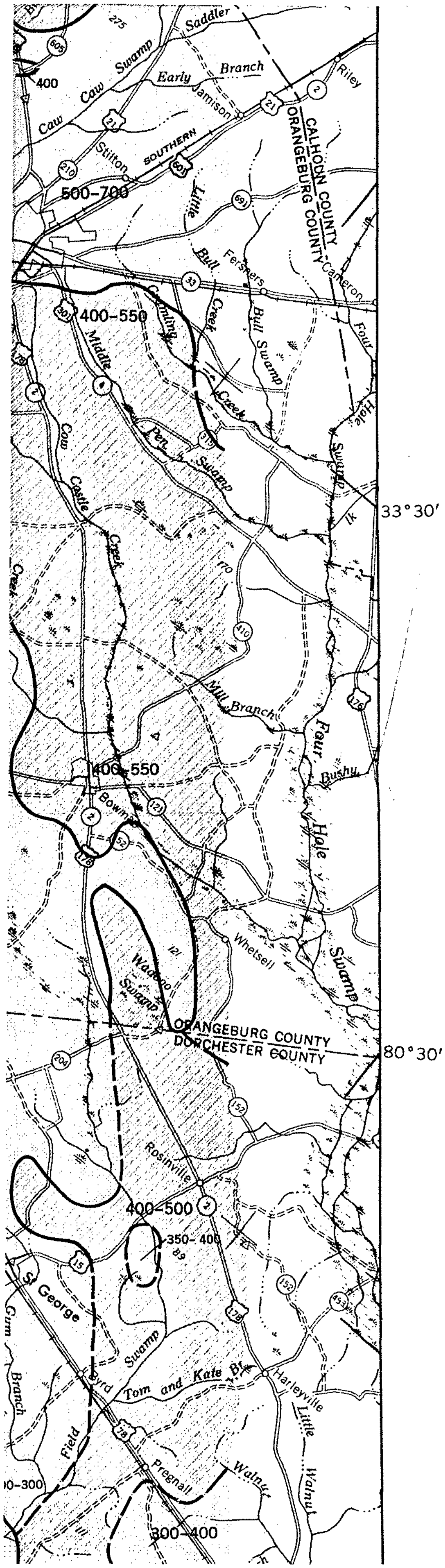
GEOLOGICAL SURVEY, WASHINGTON, D. C.— 61428

33°00′

Aeroradioactivity survey made at 500 feet above the ground under the direction of P. W. Philbin, 1958

14

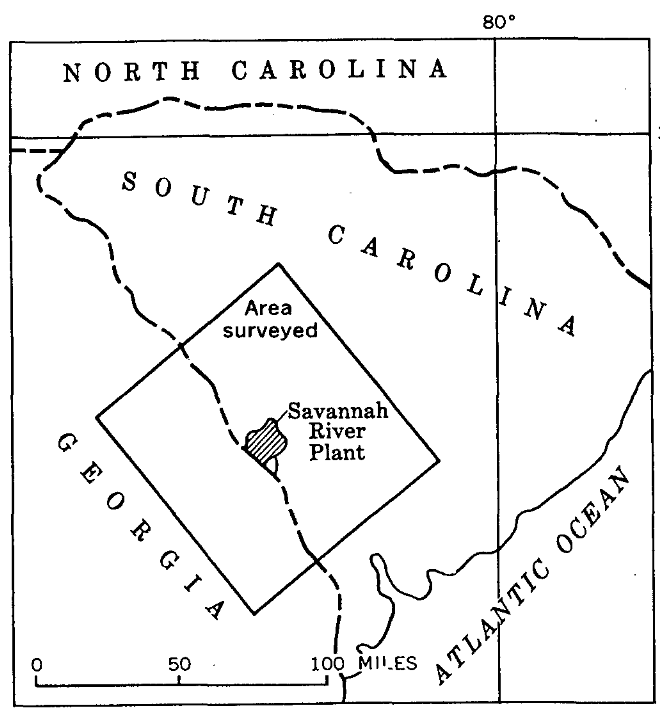
For sale by U. S. Geological Survey, price 50 cents
Washington 25, D. C.



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 affect discrimination of the radioactivity levels that reflect changes in the ground component.

The ground component comes from approximately the upper 6 inches of the ground. It consists of gamma rays from natural radionuclides, principally members of the uranium and thorium radioactive decay series and potassium-40, and from fallout of radioactive nuclear fission products. Locally, if fallout is present it must be small, as the lowest total radiation measured is 150 counts per second in areas not affected by absorption of gamma energy by water. The distribution of fallout in the area surveyed is assumed to be uniform.

1/ 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.



INDEX MAP