VIRGINIA MINERALS

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
Richmond, Virginia

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Airborne Magnetometer Survey Southwest Virginia

A precise airborne magnetometer survey of 5,000 square miles of Southwest Virginia was proposed by Dr. James L. Calver, Commissioner, Division of Mineral Resources, Virginia Department of Conservation and Economic Development, in reply to J. Lindsay Almond's request to bolster the economy of the southwestern counties.

On December 29, 1961, Governor Almond announced the allocation of $35,000 to make this survey, the results of which are expected to encourage further exploration of the area for oil and gas reserves and should have considerable value in locating and charting other minerals in the area.

The State Board of Conservation and EconomicDevelopment gave enthusiastic approval to the proposal, which was also strongly advocated by business and industrial leaders of the southwest section. A similar type airborne magnetometer survey over 13,000 square miles of Eastern Kentucky has been very helpful to industrial development. The area in Virginia to be surveyed includes portions of Grayson, Carroll, Floyd, Montgomery and Giles counties and all other counties to the west of them. Funds are being provided by the Division of Mineral Resources.

A magnetometer survey is made to measure the intensity and direction of the earth's magnetic field and to infer the distribution of rocks possessing different magnetic properties from the local variations. From this survey irregularities are discovered that reflect changes in character of the rock; however, the survey does not provide an interpretation of the causes.

It is anticipated that the planes will begin flying the grid of the survey as soon as the weather permits and will complete the work as rapidly as possible, but no later than June 30.

After July 1st, results of the survey will be made available at blueprint costs only to anyone interested upon request to Dr. Calver, State Division of Mineral Resources, P. O. Box 3667, Charlottesville.

Recommendation for [1] Topographic Mapping

Topographic maps show the configuration of land by contours, and the location of highways, secondary roads, streams, railroads, utility lines, and wooded areas. These maps greatly aid in detailed geologic studies and mineral resource evaluation studies, and are used by the mining industry, the petroleum industry, and in groundwater and surface-water studies. Data as to natural resources, terrain and transportation facilities, such as are shown on these maps, are essential in planning for development of existing industry and in attracting new industry, both of which are essential to maintenance of a sound and expanding economy in the State.

Topographic maps are prepared and printed by the Topographic Division of the United States Geological Survey. The programs for mapping areas of a state in this respect consist of a state-federal cooperative program in which funds are matched dollar for dollar, and also an independent federal program for which only federal funds are used. The present level of the cooperative mapping program in Virginia during the current biennium is at the rate of $160,000 a year, $80,000 of which is Virginia's share.

Obviously, maps made many years, and even decades, ago are inadequate, in that they not only do not reflect present physical features, but

[1] Excerpt from "Zoning, Subdivision Control, and Planning in Virginia," Report of the Virginia Advisory Legislative Council to the Governor and the General Assembly of Virginia.

also are not prepared to a scale of 1:24,000, or 1 inch equals 2,000 feet, which is considered adequate for modern purposes.

The Department of Conservation and Economic Development advises that to date only approximately 11% of the State is covered by maps in 7½ minute quadrangles that meet "modern" map standards with an additional 13% now in progress under current programs, and an additional 4% in relatively modern maps that are suitable for revision to 7½ minute quadrangles. To complete coverage of the State after June 30, 1962, with such maps, including the completion of those in progress and those capable of revision, would require a six million three hundred thirty thousand dollar program, three million one hundred sixty-five thousand dollars of which would be the State's share. This program could be carried out efficiently over a period of six years. Following such a program, it is estimated that an annual continuation program at a cost of between $130,000 and $150,000 of which the State's share would be one-half would be required to keep these maps up to date.

As hereinbefore stated, the Committee held two public hearings, one of which was devoted exclusively to the matter of topographic mapping. Officials of the State Department of Conservation and Economic Development, including the Chairman of the Board, representatives of the Virginia State Chamber of Commerce and of local chambers of commerce, heads of industrial departments of railroads operating in the State and of other industries, officials of local industrial development agencies, and of local and regional planning commissions, and city planning officials appeared on this occasion and gave testimony. These individuals were unanimous in urging that the State make available the necessary funds for early completion of full coverage of the entire area of the State by modern and adequate topographic maps. They all asserted that such maps are essential to an effort to attract new industries into a locality.

We are thoroughly in agreement with the views expressed to us in two respects. First, we concur as to the importance of the provision of adequate topographic map coverage of the State of Virginia to commerce and industry and to the economic health of the Commonwealth. It is impossible to demonstrate factually what the lack of maps has cost the State, although instances were cited to us of failure of some industries to locate in Virginia because other places could provide more information as to potential sites. There is no way of even estimating how many times industrial planners have simply overlooked Virginia sites because they had no information about them. However, the evidence presented to us indicates that this must have occurred many times.

Secondly, we agree that the present program is totally inadequate. We have been advised that the federal program contemplates a completion of the mapping of Virginia by the photogrammetric method in 7½ minute quadrangles, at a scale of 1:24,000, or 1 inch equals 2,000 feet, in twenty years. When it is realized that according to present estimates it will cost almost as much merely to keep maps up to date as the State and federal governments are now spending on the mapping program as a whole, it will readily be understood that reliance upon the federal government's twenty year plan would mean, in effect, that the State would not achieve the suggested goal of complete coverage with adequate maps until 1980 in all probability. A map made now of an area which is being rapidly developed for industrial or residential purposes would, in five years, reflect accurately only the basic terrain features and would for many purposes be almost entirely useless.

The total area of Virginia is, in round figures, 39,900 square miles. By June, 1962, 11,200 square miles will have been mapped or will have maps in progress under the modern photogrammetric method, leaving an area of approximately 28,700 square miles still to be covered in the program.

It should be mentioned that different types of maps are contemplated for different areas. In very hilly regions, for instance, a small contour interval would make a map almost unreadable, in addition to being prohibitively expensive to produce, whereas in the coastal plains, a much smaller contour interval is feasible and desirable. The proposed program contemplates the following contour intervals:

40′ contours— 2,300 square miles
20′ contours—14,000 square miles
10′ contours—11,300 square miles
5′ contours— 1,100 square miles

At the hearing on topographic mapping it was suggested that some localities in the Tidewater Area desired a one-foot contour interval map. This would be impractical on any widespread basis and the federal authorities would not participate in any such program. However, the State Highway Department does have mapping equipment and spokesmen for the Department stated that it might be possible for the Department to make special flights to produce maps of this character for special engineering projects or for industrial promotion projects. We feel that this might be desirable and accordingly recommend enabling legislation to permit the Highway Department, upon the request of a local governing body or nonprofit agencies interested in industrial development, concurred in by the Department of Conservation and Economic Development, to make such maps or plats, the Highway Department being reimbursed for the cost thereof by the local governing body or agency making the request, with such help as the Department of Conservation and Economic Development is able to give.

The recommended program calls for the expenditure over a six-year period of approximately $6,330,000 of combined State and federal funds. The suggested allocation of these expenditures by years is set forth below:

1st year	$ 650,000
2nd year	1,400,000
3rd year	1,600,000
4th year	1,600,000
5th year	900,000
6th year	180,000

We reiterate that we endorse the six-year program as a goal. We feel that there are few ways in which the State could more profitably invest these funds and that money spent in providing topographic maps as planned will shortly be returned to the State in taxes paid by industry, which will be the primary beneficiary of the mapping program.

In the carrying out of the program, however, we believe that a system of priorities should be established which would produce the greatest return for the money spent in the shortest time. Industry tends to locate in areas where the population insures an adequate labor supply and where necessary facilities and services can be readily provided. For this reason the major metropolitan areas would appear to be those to which first attention should be given. An additional reason which suggests this priority is the fact that in several of these areas existing maps are available which can be brought up to date at a much smaller cost than would be required for entirely new maps. Of the sixty-two quadrangles involved in the major metropolitan areas, twenty-nine have maps which can be brought up to date and only thirty-three would require new maps. The total cost of the program in these areas, including new maps and updated quadrangles, is $578,940. To complete the program for the smaller metropolitan and city areas, on the other hand, will require the making of new maps for 145 out of the 163 quadrangles involved and only 18 are covered by maps which can be brought up to date. The cost of the program in these areas is $1,712,200.

To complete the present cooperative mapping program currently in progress will require the expenditure of $393,000 and to revise the relatively modern maps that are suitable for revision to 7½ minute quadrangles would cost an additional $128,000. Of this total of $521,000, one-half would be borne by the State.

While we do not believe that it is the function of the legislature to establish by statute priorities which should be fixed by the exercise of sound administrative judgment, we suggest that the above three programs be given priority in the detailed planning for the expenditure of such funds as are made available.

Evidence was presented at the hearing which showed that many states in competition with Virginia have joined in the federal-state cooperative mapping program, and that many have completed their initial program and are now engaged in the revision of their "modern" maps. We do not feel that Virginia can afford to be second best in the tools which we can provide our citizens in furthering the desired industrial development of the Commonwealth.

Addition to Staff

Mr. Merrick S. Whitfield, Jr. has recently joined the Division and will assist in ground-water studies. He received his B. S. degree in geology from Baylor University, Waco, Texas, in 1959, after an interruption of two years with the U. S. Army Signal Corps. He was employed by the Baroid Division of the National Lead Company as a well logging engineer and later with the Humble Oil Company in the geophysical section. He entered graduate school at Louisiana Polytechnic Institute, Ruston, Louisiana, from which he received his M. S. degree in geology. Mr. Whitfield fills the position that was recently vacated by Dr. H. R. Hopkins.

Flouride In Well Waters Of The Virginia Coastal Plain[1]

By ALLEN SINNOTT and GEORGE W. WHETSTONE[2]

Ground water, which is contained in crevices and pore spaces of the rocks and soil mantle, is generally withdrawn for human use through wells and springs. The mineral matter in ground water is dissolved principally from the rocks and soils through which it moves; it commonly contains 1/10 of 1 percent by weight (1,000 parts per million) or less of dissolved mineral matter. The mineral constituents that have a practical bearing on the utility of the ground water for most purposes are silica, iron, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, fluoride, and nitrate. Many of these dissolved constituents have characteristic effects when present in sufficient amounts. Among the minor constituents, fluoride is notable for its important physiological effects even when present in low concentrations. In ground water it is chiefly of interest in relation to domestic use by families with growing children.

In 1931, Smith, Lantz, and Smith (1931), Churchill (1931, p. 996-998), and Velu (1931, p. 750-752), in three independent investigations, demonstrated the relation between the presence of fluoride in drinking water and the incidence of mottled enamel in the teeth of persons who, as children less than about 12 years of age, regularly drank the water. These papers stimulated much of the subsequent research on this subject. Five years later, Dean (1936, p. 1269-1272) showed that water containing 1.7 to 1.8 ppm (parts per million) of fluoride may be expected to cause mild forms of mottled enamel in nearly 50 percent of children using such water. In 1942, Dean and others (p. 1176-1177) found that the fluoride ion, in concentrations of about 1.0 ppm in drinking water for children, seems to aid materially in preventing dental caries (tooth decay). (In recent years, it has been accepted generally that the maximum concentration that can be used safely by most children under the age of about 10 years is 1.5 ppm.) As a result of this discovery, many communities in the United States have added small amounts of fluoride to their public drinking-water supplies in order to reduce tooth decay among children. Because of this interest on the part of health authorities in fluoride in water supplies, the U. S. Geological Survey regularly makes fluoride-ion determinations in practically all chemical analyses of ground waters and surface waters.

Fluoride In Ground Water

The concentration of fluoride was determined in about three-hundred samples of ground water collected from wells tapping rocks that range in geologic age from Cretaceous to Quaternary forming the Virginia Coastal Plain. These rocks consist of sedimentary layers of unconsolidated clays, sands, and marls, with minor interbedded gravel lenses; these rest on a basement complex of hard igneous and metamorphic rocks, mostly of Precambrian age, and sandstones of Triassic age. The sedimentary formations thin westward to a featheredge against the crystalline complex of the Piedmont province along the Fall Line—a north-south belt of falls and rapids extending from Washington through Fredericksburg, Richmond, and Petersburg to Emporia, where the hard basement rocks crop out along the western border of the Coastal Plain (fig. 1). The sedimentary strata, which carry practically all the ground water in the Coastal Plain, dip gently seaward at an average rate of a few tens of feet per mile (fig. 2).

The ground waters for which determinations of fluoride are available have been classified according to the geologic age of the aquifers from which they were derived in an effort to learn whether some stratigraphic relationship might exist. The fluoride concentrations have been plotted on maps of the Coastal Plain (figs. 3-6) in the form of pie graphs that show, by the sizes of the filled sectors, the concentrations of fluoride found at each source. The following generalizations are based on these maps.

The youngest rocks in the Coastal Plain form a veneer of clayey sand and gravel capping the older rocks. They range in thickness from 0 to

[1] This article is based on work done during a Federal-State cooperative program that was terminated in June 1957. It is also in part based on an earlier short paper by the same writers published in 1950. Publication authorized by the Director of the Geological Survey, U. S. Department of the Interior.

[2] U. S. Geological Survey.

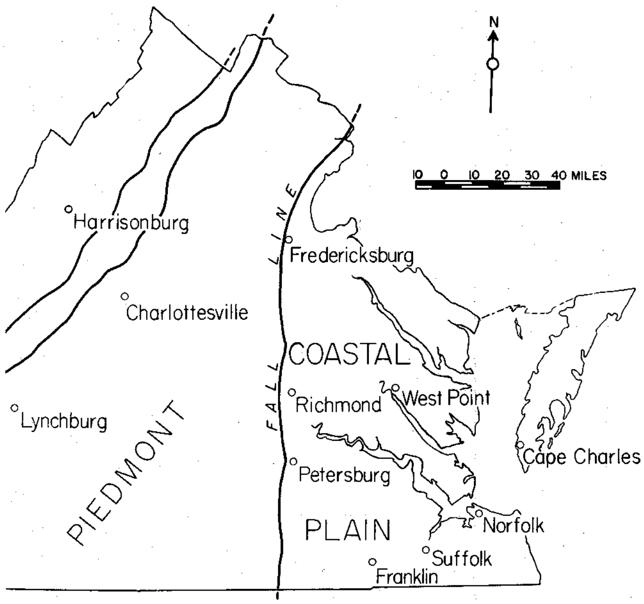

Figure 1—Physiographic divisions of Virginia.

about 60 feet, and are of Quaternary age, mostly Pleistocene. Many thousands of shallow-dug and driven wells and many springs tap water from these sediments. Throughout the Coastal Plain, the water from these wells and springs is low in fluoride. The analyses indicate that water from Quaternary deposits generally contains about 0.1 ppm of fluoride. The range in concentration of fluoride in water from wells producing from the Quaternary is rather small; the highest concentration is only 0.5 ppm (fig. 3).

Underlying the Pleistocene sediments in the eastern part of the Coastal Plain are Tertiary rocks of Miocene and Eocene age. Water of slightly higher fluoride concentration, averaging about 0.6 ppm, is found in water from wells tapping Miocene rocks; however, concentrations of as much as 2 ppm are found in waters from a few wells in Miocene rocks in Lancaster and York counties (fig. 4).

Underlying the Miocene rocks throughout most of the Coastal Plain are sands of Eocene age that are characteristically high in the mineral glauconite. The average concentration of fluoride in waters from these rocks is about 1.7 ppm, or slightly greater than the generally accepted maximum concentration of 1.5 ppm (U. S. Public Health Service, 1946). Most of the wells tapping these Eocene aquifers in the lower York-James Peninsula yield waters containing substantially more than 1.5 ppm of fluoride. Locally, as in eastern Surry County, lower James City County, and southeastern Lancaster County, the fluoride content may exceed 3 ppm (fig. 5).

The highest fluoride concentrations in ground waters in the Virginia Coastal Plain are found in the waters from aquifers of Cretaceous age. These rocks are unconsolidated deltaic deposits of clay, sand, and gravel. They underlie the older Tertiary (Eocene) deposits throughout most of the Coastal Plain, but locally are capped by the younger Tertiary (Miocene) or Quaternary (Pleistocene) rocks, and they crop out, to a limited extent, along river valleys just east of the Fall Zone. Many of the samples of water from wells tapping Cretaceous rocks in the western part of the Coastal Plain contain low concentrations of fluoride. However, in the southeastern part of the Coastal Plain, in Nansemond, Isle of Wight, and Southampton counties, many well waters are high in fluoride, some reaching concentrations of 7.5 ppm. Widely separated samples of water from Cretaceous aquifers in other parts of the Coastal Plain show fluoride concentrations as high as 4 ppm, as in water from wells in Surry and Lancaster counties and

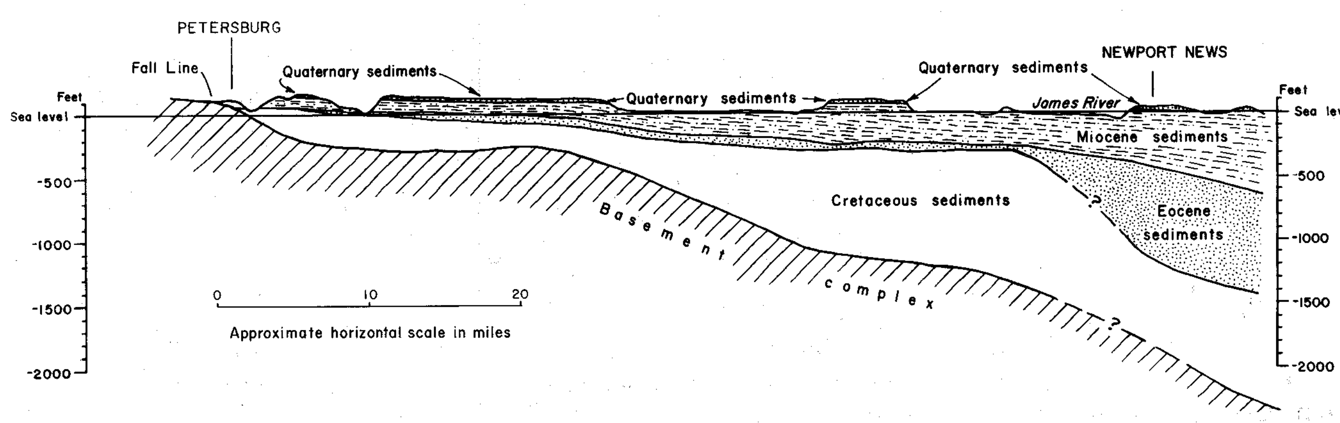

Figure 2 — Generalized geologic section across the Virginia Coastal Plain showing the major stratigraphic units. Vertical exaggeration, 40X. (After Cederstrom, 1945, plate 1.)

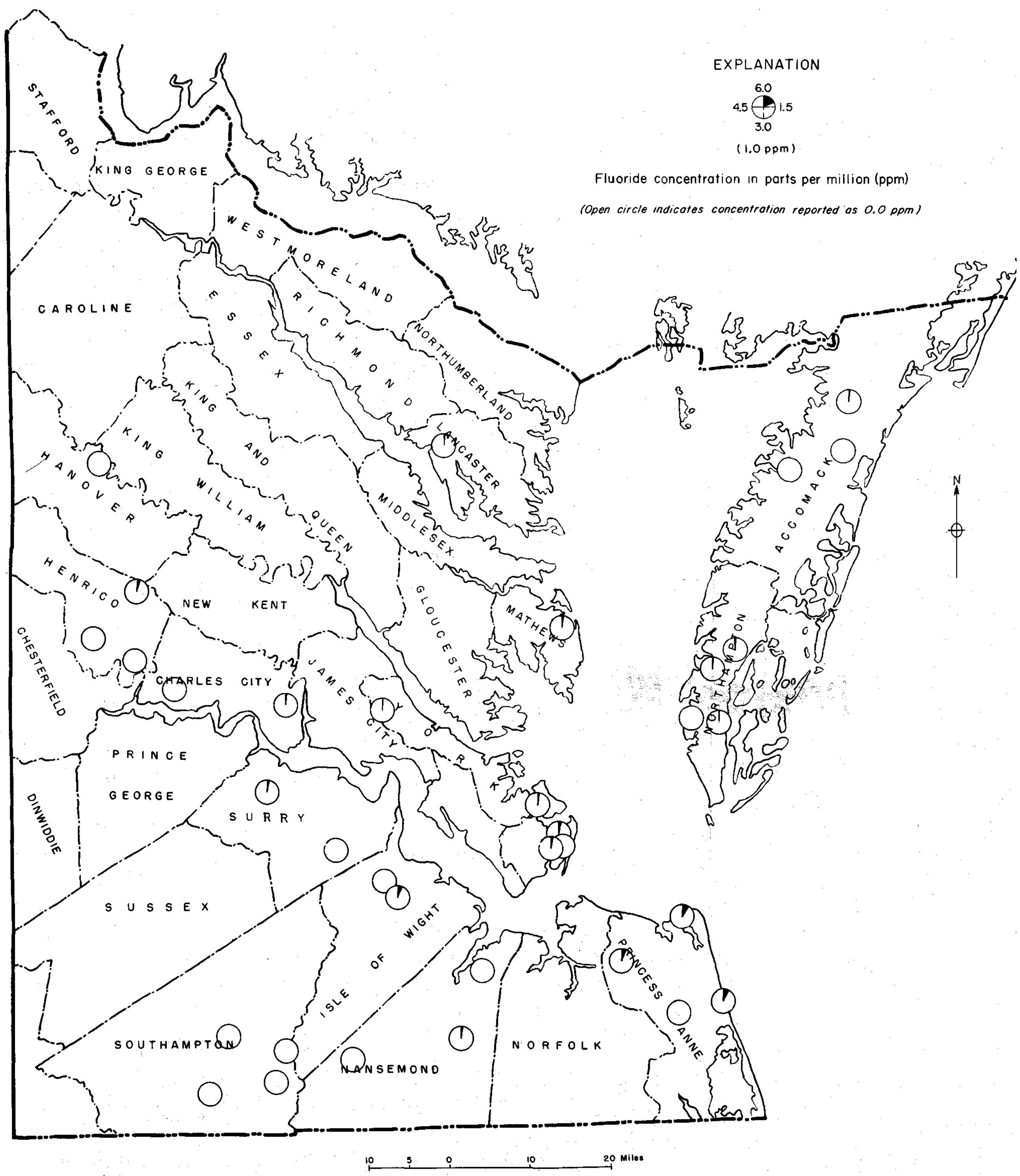

Figure 3 — Distribution of fluoride in ground waters from rocks of Quaternary age, Virginia Coastal Plain.

on Tangier and Smith islands in Chesapeake Bay (fig. 6). The average fluoride content of waters from Cretaceous aquifers, based on available analyses, is 2.7 ppm. Thus, ground water from Cretaceous aquifers, tapped by most of the large wells in the Coastal Plain south of James River, like waters from Eocene aquifers, tapped by most large wells on the York-James Peninsula, may be expected to contain fluoride in objectionable amounts.

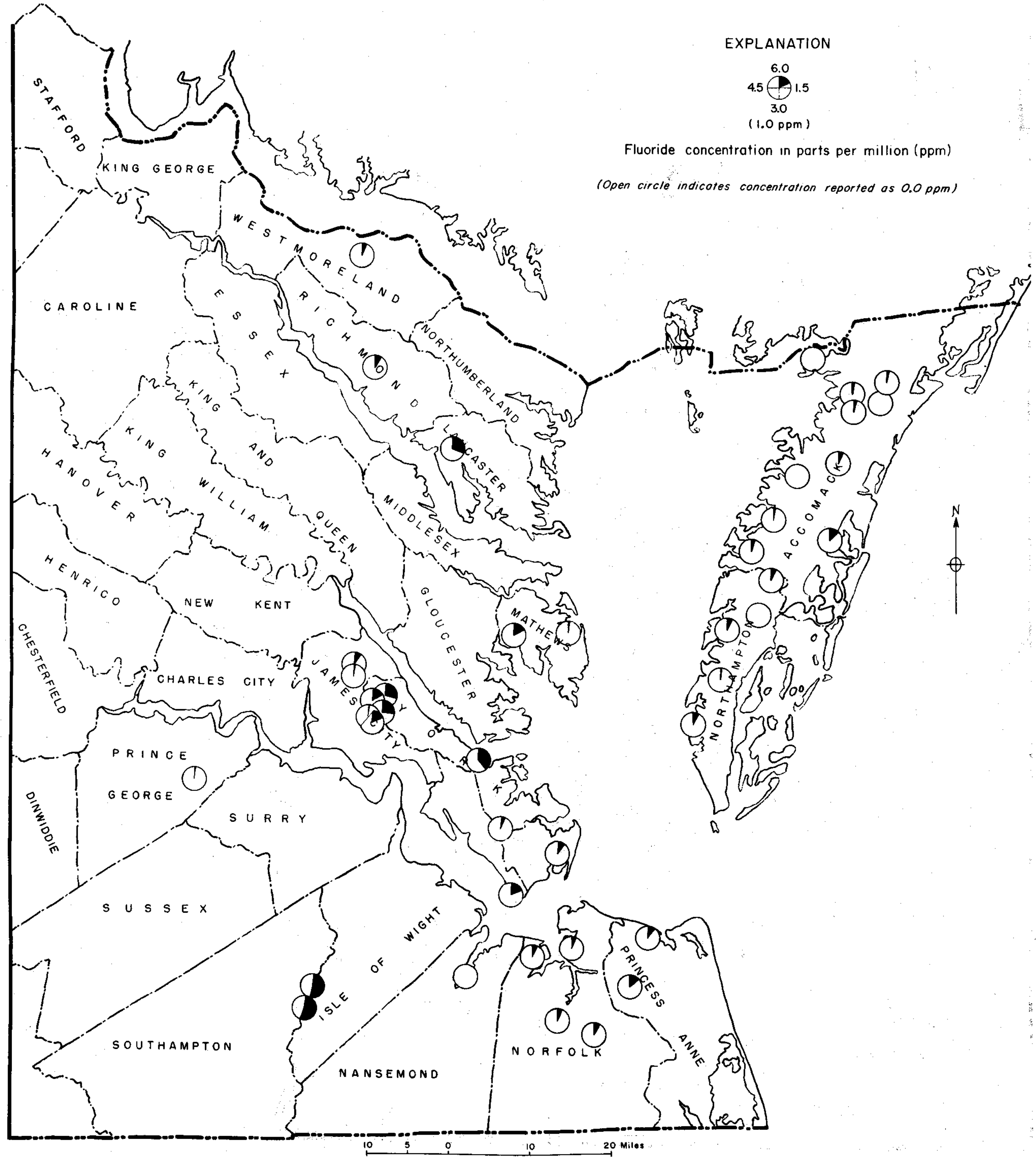

Figure 4 — Distribution of fluoride in ground waters from rocks of Miocene (Tertiary) age, Virginia Coastal Plain.

Source Of Fluoride

Hem (1959, p. 112-113) reports that the solubilities of various fluoride salts limit the amounts of fluoride found in natural waters. The solubility of calcium fluoride (about 8.7 ppm of fluoride) limits the concentration of fluoride in waters that have more than about 10 ppm of calcium in solution. Sodium fluoride is very soluble in water and most of the fluoride concentrations over 1 ppm in analyses studied by Hem occurred in sodium waters.

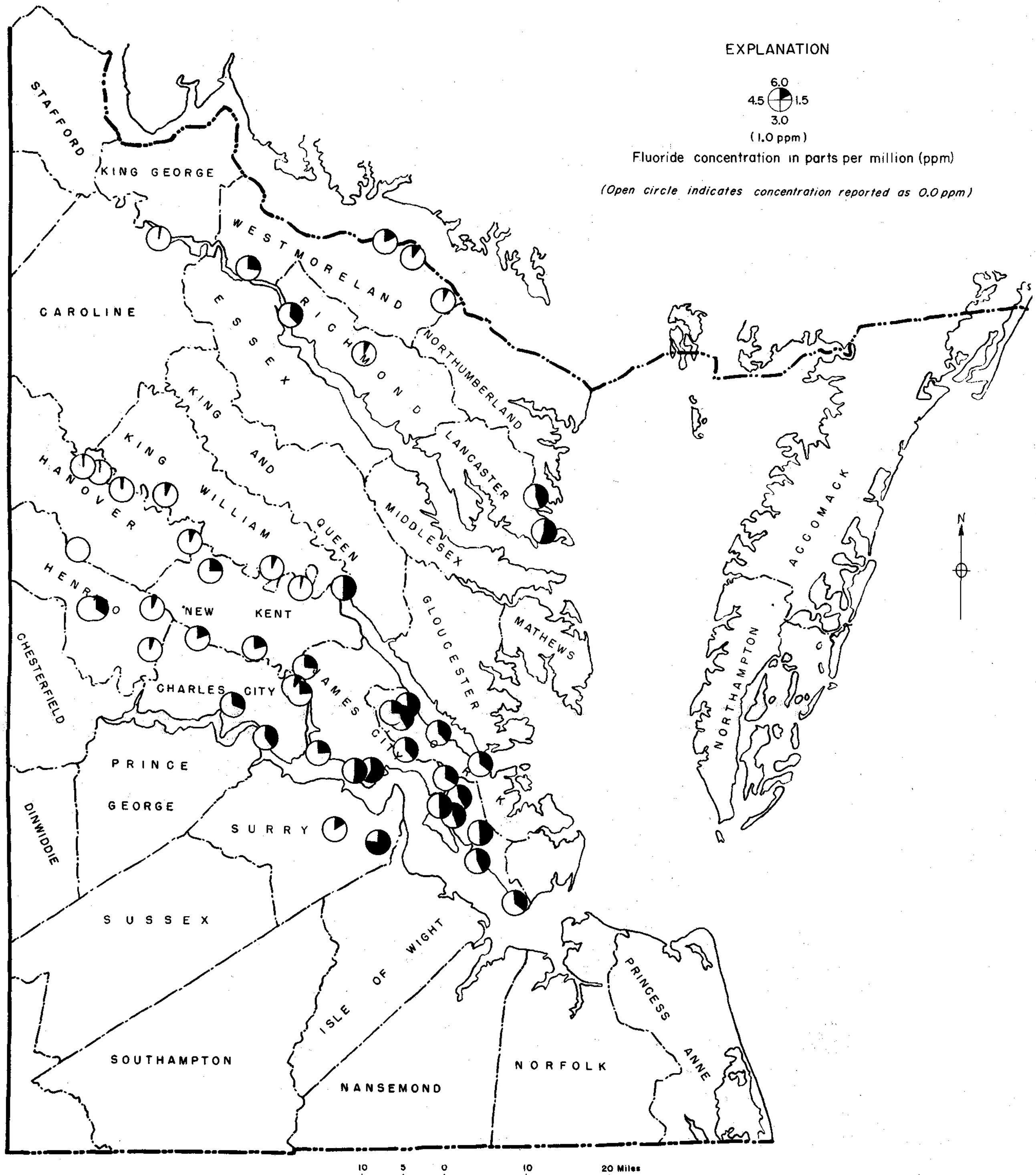

Figure 5 — Distribution of fluoride in ground waters from rocks of Eocene (Tertiary) age, Virginia Coastal Plain.

Appreciable amounts of fluoride are found in soft sodium bicarbonate ground waters in many places throughout the United States. This relation is discussed in several papers on ground-water conditions in the Atlantic and Gulf Coastal Plains (Carlston, 1942; Cederstrom, 1945; and LaMoreaux, 1948). Other types of ground waters in this region—for example, hard calcium bicarbonate waters—apparently seldom contain more than a few tenths of a ppm of fluoride in

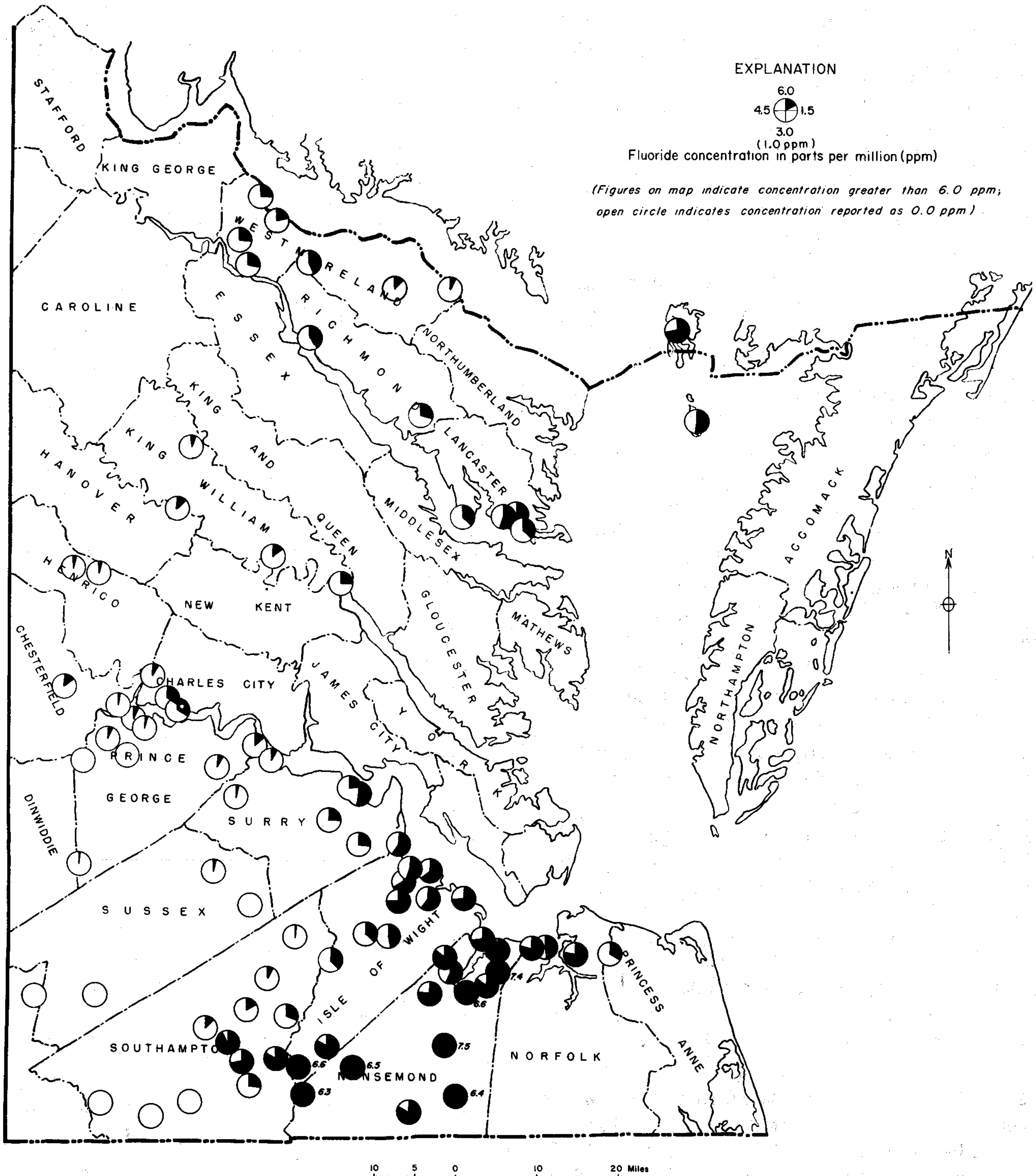

Figure 6. — Distribution of fluoride in ground waters from rocks of Cretaceous age, Virginia Coastal Plain.

solution. Most surface waters in Virginia contain about 0.1 ppm of fluoride. Thus, it would seem that the fluoride ion, derived possibly from some widely distributed clay mineral or from muscovite and sericite micas, as suggested by Cederstrom (1945, p. 112), are more readily soluble in the soft sodium bicarbonate waters. However, as Cederstrom (1945, p. 110) points out, according to experimental data, several ppm of fluoride can be leached from glauconitic sediments by other types of water. Apparently, then, the postulated solvent action of soft sodium bicarbonate ground water is not the only factor involved in the release of fluoride from its source minerals; this factor is, however, significant because these sodium bicarbonate waters are frequently encountered in the deep wells of the Coastal Plain.

The extremely small amounts of fluoride in water support Cederstrom's view that traces of the element in certain clays and micas might be the source of the fluoride. In areas where fluoride concentrations are considerably more than 1.0 ppm, as in Franklin and Courtland in southeastern Virginia, and on Tangier and Smith islands in Chesapeake Bay, the writers suspect that local abundance of fluoride-bearing minerals in the sediments, such as apatite, tourmaline and topaz, may be an important contributing factor. Gwynne (1934, p. 139-140) suggests that fluoride may be released to ground waters by the action on such minerals of extremely dilute sulfuric acid formed from the decomposition of pyrite. Van Burkalow (1946, p. 187-188), following Gwynne's theory, states that fluoride in ground water results from an abundance of fluoride-bearing minerals in the aquifers, associated with pyrite and organic matter which facilitate the decomposition of these minerals. LaMoreaux (1948, p. 32) suggests that this process might account in part for the fluoride content of the ground waters from the Cretaceous and Tertiary rocks of the Alabama Coastal Plain.

The two accompanying tables summarize the available data on the fluoride content of ground and surface waters of the Virginia Coastal Plain. Although data on the concentrations of fluoride in ground waters in other sections of Virginia are meager, the concentrations in surface water throughout the Commonwealth are less than 0.3 ppm. The surface-water data have been included for comparison and also to stress the fact that, although these waters contain very little fluoride, they nevertheless are the principal replenishers of the artesian ground waters in the Coastal Plain which are there found to be high in fluoride content. It follows that the fluoride found in these artesian waters must have its source among the minerals composing the sediments through which the waters pass.

Table 1 — Average fluoride concentrations in ground waters of the Virginia Coastal Plain

Source (by geologic age of aquifers)	Fluoride concentration, in parts per million
Quaternary—Pleistocene (61 analyses)	0.1
Tertiary—Miocene (45 analyses)	.6
Tertiary—Eocene (71 analyses)	1.7
Cretaceous (121 analyses)	2.7

Table 2 — Average fluoride concentrations in typical surface waters in the Virginia Coastal Plain.

Source	Number of analyses	Fluoride concentration, in parts per million
Occoquan Creek, near Occoquan	36	0.1
Mattaponi River, near Bowling Green	36	.1
Mattaponi River, near Beulahville	36	.1
James River, at Richmond	72	.1
Blackwater River, at Zuni	36	.0
Nottoway River, near Sebrell	36	.1
Pamunkey River, near Hanover	36	.1

Reduction Of Fluoride Concentration

The problem of the removal or reduction of the amount of fluoride in public water supplies in order to help prevent mottled enamel has been considered by several workers. Elvove (1937) shows that it is possible by means of chemicals such as tricalcium phosphate, magnesium oxide, and magnesium hydroxide to reduce high concentrations of fluoride in water supplies.

Processed tricalcium phosphate composed of granules of $Ca_3P_2O_8.H_2O$ and $3Ca_3P_2O_8.Ca(OH)_2$ removes fluorides by ion exchange. Degreased, protein-free bone reacts in a similar manner. The excess lime treatment of high magnesium waters produces magnesium hydroxide:

$$Mg(HCO_3)_2+2Ca(OH)_2=Mg(OH)_2+2CaCO_3+2H_2O$$

Fair and Geyer (1954) report that fluoride removal appears to be due to adsorption of F− on the $Mg(OH)_2$ floc. The reduction of 3 ppm of F− to 1.0 ppm requires the precipitation of 100 ppm of Mg^{++}. In the absence of significant amounts of magnesium in the water, as occurs in many of the Coastal Plain ground waters, a magnesium salt can be added to bring about the desired concentration for fluoride removal. These practices, although obviously desirable, may not be economically feasible in many cases.

In some localities, carefully controlled dilution of the main water supply with low-fluoride water may be a practical solution to the problem. Dean (1936, p. 750-752) suggests that low fluoride water of otherwise satisfactory quality may be tapped for limited distribution to the younger children. This was later suggested by Cederstrom (1945, p. 246) for certain areas in southeastern Virginia.

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The Mineral Industry of Virginia in 1961[1]

Mineral production in Virginia in 1961 was valued at $207 million, a 2 percent increase above 1960, according to estimates by the Bureau of Mines, United States Department of the Interior. The year 1961 was the sixth year in succession to record a mineral production value in excess of $200 million. The increase was attributed primarily to increased output of stone, cement, and sand and gravel, reflecting increased construction activity in the State. Output and value of most other minerals remained relatively stable.

Mineral Fuels

Output of coal totaled 27.7 million tons, a decrease of less than 1 percent compared with 1960. Coal value accounted for over half of the State's total mineral value. Production of natural gas and crude petroleum increased; a slight increase in the average unit value for natural gas was recorded for 1961.

Nonmetals

Demands for aggregates in the construction industry increased and resulted in increased out-

[1] Prepared December 18, 1961, by Joseph Krickich, Mineral Specialist, under the supervision of Robert D. Thomson, Acting Chief, Pittsburgh Office of Mineral Resources, Region V, U. S. Bureau of Mines. From Area Report H-209.

Division of Mineral Resources

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put of stone and sand and gravel and increased shipments of portland and masonry cements. Total stone production increased primarily due to increased output of crushed limestone and granite, the State's leading stones. Output and value of other types of stone was about the same as in 1960. Output of all other nonmetallic minerals except lime, pyrites, salt, and soapstone, increased slightly.

Metals

Production of all metallic minerals except titanium concentrate (ilmenite and rutile) increased from the previous year. Lead and zinc values were affected by a drop in the average market price for these metals. Although output of titanium concentrate declined, a 12 percent increase in the average unit value was recorded.

Table 1. — Mineral Production in Virginia [1]

	1960		*Preliminary 1961*	
	Quantity	*Value (thousands)*	*Quantity*	*Value (thousands)*
Clays ....thousand short tons	1,348	$ 1,395	1,404	$ 1,466
Coal ....do........	27,838	122,723	27,720	(2)
Gem stones	[3]	5	[3]	6
Lead (recoverable content of ores, etc.) ....short tons	2,152	504	3,948	845
Lime ....thousand short tons	711	8,028	542	6,120
Mica, sheet ....pounds	103	1	(2)	(2)
Natural gas ....million cubic feet	2,227	604	2,300	650
Petroleum (crude) ....thousand 42-gallon barrels	2	[2]	6	[2]
Sand and gravel.....thousand short tons	7,666	11,432	8,153	12,194
Stone ....do.......	19,358	33,019	20,846	35,619
Zinc (recoverable content of ores, etc.)[4] ....short tons	19,885	5,142	29,730	6,838
Value of items that cannot be disclosed: Aplite, portland cement, masonry cement, feldspar, gypsum, iron ore (pigment material) kyanite, pyrites, salt, soapstone, titanium concentrate (ilmenite and rutile) and values indicated by footnote [2]		25,951 [5]		147,659
Total Virginia [6]		203,812 [5]		206,895

[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
[2] Figure withheld to avoid disclosing individual company confidential data.
[3] Weight not recorded.
[4] Recoverable zinc valued at the yearly average price of Prime Western slab zinc, East St. Louis market. Represents value established after transportation, smelting, and manufacturing charges have been added to the value of ore at the mine.
[5] Revised figure.
[6] Total adjusted to eliminate duplicating value of clays and stone.