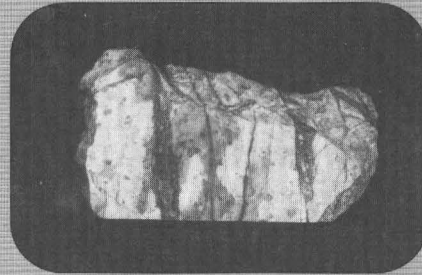
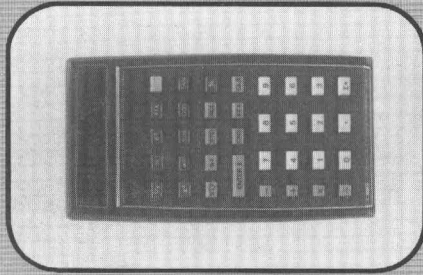
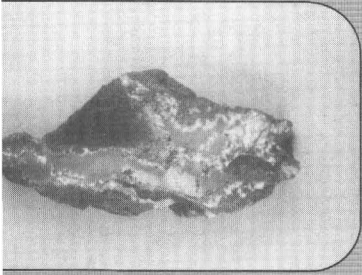
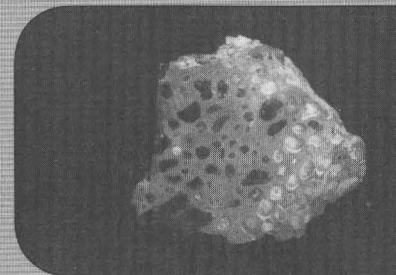
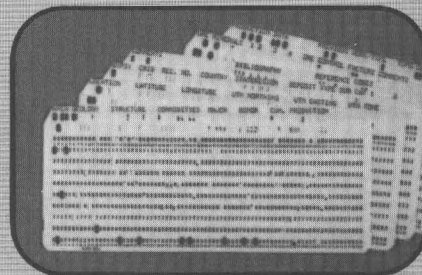
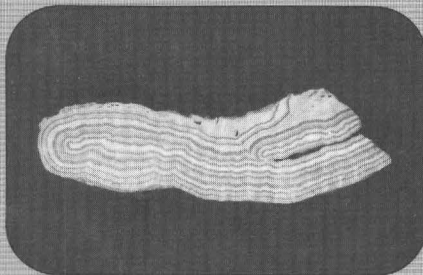
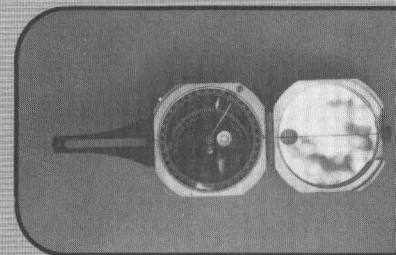
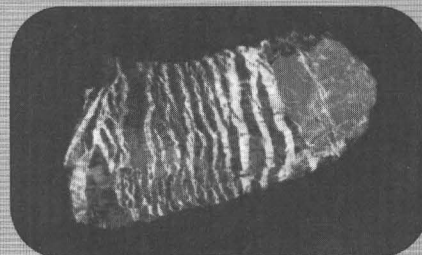
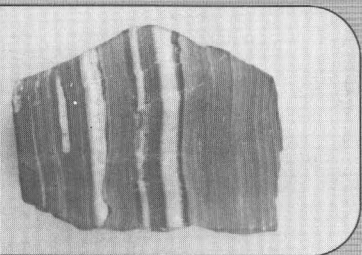
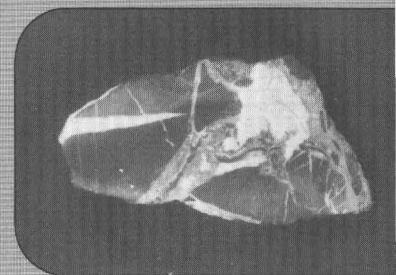
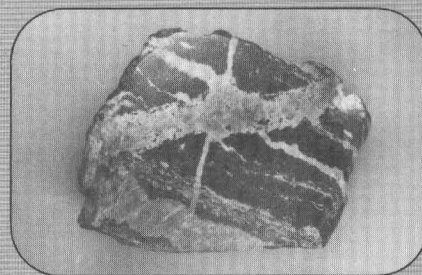
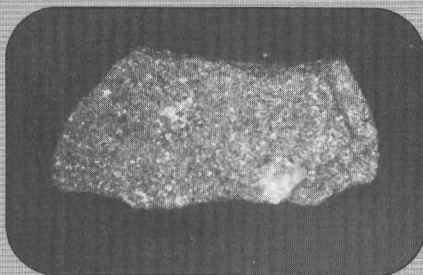
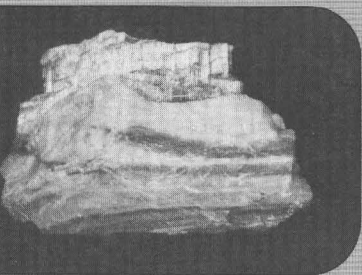


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ALLUVIAL ILMENITE PLACER DEPOSITS, CENTRAL VIRGINIA

GEOLOGICAL SURVEY PROFESSIONAL PAPER 959 H



COVER PHOTOGRAPHS

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- Asbestos ore
- Lead ore-Balmat Mine, N. Y.
- Chromite-chromium ore, Wash.
- Zinc ore-Friedensville, Pa.
- Banded iron formation, Palmer, Michigan
- Ribbon asbestos ore, Quebec, Canada
- Manganese ore, banded rhodochrosite
- Aluminum ore, bauxite, Georgia
- Native copper ore, Keweenaw Peninsula, Mich.
- Porphyry molybdenum ore, Colo.
- Zinc ore, Edwards, N. Y.
- Manganese nodules, ocean floor
- Botryoidal fluorite ore, Poncha Springs, Colo.
- Tungsten ore, North Carolina

Alluvial Ilmenite Placer Deposits, Central Virginia

By J. P. MINARD, E. R. FORCE, and G. W. HAYES

G E O L O G Y A N D R E S O U R C E S O F T I T A N I U M

G E O L O G I C A L S U R V E Y P R O F E S S I O N A L P A P E R 9 5 9 - H

*A discussion of ilmenite placers in alluvial
deposits along streams draining the
Roseland Anorthosite and nearby areas,
and their economic potential*



UNITED STATES DEPARTMENT OF THE INTERIOR

THOMAS S. KLEPPE, *Secretary*

GEOLOGICAL SURVEY

V. E. McKelvey, *Director*

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APPRAISAL OF MINERAL RESOURCES

Continuing appraisal of the mineral resources of the United States is conducted by the U.S. Geological Survey in accordance with the provisions of the Mining and Minerals Policy Act of 1970 (Public Law 91-631, Dec. 31, 1970). Total resources for purposes of these appraisal estimates include currently minable resources (*reserves*) as well as those resources not yet discovered or not presently profitable to mine.

The mining of mineral deposits, once discovered, depends on geologic, economic, and technologic factors; however, identification of many deposits yet to be discovered, owing to incomplete knowledge of their distribution in the Earth's crust, depends greatly on geologic availability and man's ingenuity. Consequently, appraisal of mineral resources results in approximations, subject to constant change as known deposits are depleted, new deposits are found, new extractive technology and uses are developed, and new geologic knowledge and theories indicate new areas favorable for exploration.

This professional paper discusses aspects of the geology of titanium as a framework for appraising resources of this commodity in the light of today's technology, economics, and geologic knowledge.

Other Geological Survey publications relating to the appraisal of resources of specific mineral commodities include the following:

Professional Paper 820—"United States Mineral Resources"

Professional Paper 907—"Geology and Resources of Copper"

Professional Paper 926—"Geology and Resources of Vanadium Deposits"

Professional Paper 933—"Geology and Resources of Fluorine in the United States"

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METRIC-ENGLISH EQUIVALENTS

Metric unit	English equivalent	
Length		
millimetre (mm)	=	0.03937 inch (in)
metre (m)	=	3.28 feet (ft)
kilometre (km)	=	.62 mile (mi)
Area		
square metre (m ²)	=	10.76 square feet (ft ²)
square kilometre (km ²)	=	.386 square mile (mi ²)
hectare (ha)	=	2.47 acres
Volume		
cubic centimetre (cm ³)	=	0.061 cubic inch (in ³)
litre (l)	=	61.03 cubic inches
cubic metre (m ³)	=	35.31 cubic feet (ft ³)
cubic metre	=	.00081 acre-foot (acre-ft)
cubic hectometre (hm ³)	=	810.7 acre-feet
litre	=	2.113 pints (pt)
litre	=	1.06 quarts (qt)
litre	=	.26 gallon (gal)
cubic metre	=	.00026 million gallons (Mgal or 10 ⁶ gal)
cubic metre	=	6.290 barrels (bbl) (1 bbl=42 gal)
Weight		
gram (g)	=	0.035 ounce, avoirdupois (oz avdp)
gram	=	.0022 pound, avoirdupois (lb avdp)
tonne (t)	=	1.1 tons, short (2,000 lb)
tonne	=	.98 ton, long (2,240 lb)
Specific combinations		
kilogram per square centimetre (kg/cm ²)	=	0.96 atmosphere (atm)
kilogram per square centimetre	=	.98 bar (0.9869 atm)
cubic metre per second (m ³ /s)	=	35.3 cubic feet per second (ft ³ /s)

Metric unit	English equivalent	
Specific combinations—Continued		
litre per second (l/s)	=	.0353 cubic foot per second
cubic metre per second per square kilometre [(m ³ /s)/km ²]	=	91.47 cubic feet per second per square mile [(ft ³ /s)/mi ²]
metre per day (m/d)	=	3.28 feet per day (hydraulic conductivity) (ft/d)
metre per kilometre (m/km)	=	5.28 feet per mile (ft/mi)
kilometre per hour (km/h)	=	.9113 foot per second (ft/s)
metre per second (m/s)	=	3.28 feet per second
metre squared per day (m ² /d)	=	10.764 feet squared per day (ft ² /d) (transmissivity)
cubic metre per second (m ³ /s)	=	22.826 million gallons per day (Mgal/d)
cubic metre per minute (m ³ /min)	=	264.2 gallons per minute (gal/min)
litre per second (l/s)	=	15.85 gallons per minute
litre per second per metre [(l/s)/m]	=	4.83 gallons per minute per foot [(gal/min)/ft]
kilometre per hour (km/h)	=	.62 mile per hour (mi/h)
metre per second (m/s)	=	2.237 miles per hour
gram per cubic centimetre (g/cm ³)	=	62.43 pounds per cubic foot (lb/ft ³)
gram per square centimetre (g/cm ²)	=	2.048 pounds per square foot (lb/ft ²)
gram per square centimetre	=	.0142 pound per square inch (lb/in ²)
Temperature		
degree Celsius (°C)	=	1.8 degrees Fahrenheit (°F)
degrees Celsius (temperature)	=	[(1.8 × °C) + 32] degrees Fahrenheit

GEOLOGY AND RESOURCES OF TITANIUM

ALLUVIAL ILMENITE PLACER DEPOSITS, CENTRAL VIRGINIA

By J. P. MINARD, E. R. FORCE, and G. W. HAYES

ABSTRACT

Point bars and flood plains along rivers draining the Roseland, Va., anorthosite body and nearby mountain areas in the Blue Ridge physiographic province contain placer deposits in which there are significant amounts of rutile and ilmenite. Highest values generally are in deposits closest to the sources. Although high values (4 percent ilmenite with some rutile) seem to be associated with deposits along streams draining the area of anorthosite, equally high values are present along some streams where the source of titanium minerals is not anorthosite but hypersthene-bearing gneisses in the Pedlar Formation of Bloomer and Werner (1955). Therefore, sources of titanium minerals may be not only the small anorthosite body but also the much more widespread gneisses of the Virginia Blue Ridge. Values decrease from as much as 9 percent in alluvial placers on the anorthosite body along the Tye River to about 1 percent 80 km downstream along the James River. The higher values upstream are generally in small deposits, whereas the low values downstream are in large deposits. Downstream movement of heavy minerals over long periods of time may have resulted in further concentrations in such Coastal Plain deposits as tidal deltas and beach ridges.

INTRODUCTION

The purpose of this paper is to report the result of a study of rutile and ilmenite alluvial placer deposits in, near, and downstream from the Roseland rutile district in central Virginia. The heart of the district is in Nelson and Amherst Counties (fig. 1); this area was one of the most important sources of ilmenite and rutile for many years. Early in this century, the entire world supply of rutile came from this district, and it continued as an important contributor until 1949. Recently the plant ceased operations. However, large resources of both rutile and ilmenite may still be present, and it is hoped that this report may help stimulate further interest in the potential of the area, as was suggested by Herz and others (1970).

Herz and others (1970) reported ilmenite- and rutile-rich sediments in streams draining the Rose-

land Anorthosite, with which the titanium minerals seem to be associated. Their study included analyses of 31 samples of sand and gravel collected from the upper 15–30 cm of riffle deposits in the present stream channels. Most of their samples were collected in streams on the anorthosite body or immediately adjacent to it; two samples were collected in channels several kilometres downstream from the anorthosite (Herz and others, 1970, pl. 1). They concluded (p. F8) “that valuable deposits may have been created by stream action” and recommended that “To fully evaluate the available resources of ilmenite and rutile, churn drilling and detailed mapping in stream valleys will have to be carried out.”

The present study was partly guided by these suggestions. The area studied is larger than that of Herz and others and includes the drainage basins of the South Fork Rockfish River, Tye River, and Buffalo River, all tributaries to the James River, and along the James in the general area where these rivers flow into it. The area of this report includes parts of Nelson, Amherst, Albemarle, and Buckingham Counties (fig. 1). Some reconnaissance sampling was also done downstream from this area along the James River.

GENERAL GEOLOGY

The Roseland district is in the Blue Ridge province. The general geology in the area was described by Watson and Taber (1913), Bloomer and Werner (1955), and Herz (1968). Rock types presently drained by the local streams discussed in this report include Roseland Anorthosite, hypersthene gneiss and products of its incomplete retrograde metamorphism, biotite gneiss, migmatite, schist, granitic igneous rocks, and greenstone. The upper reaches of the James River, however, which are well outside the study area, drain sedimentary rocks of the Val-

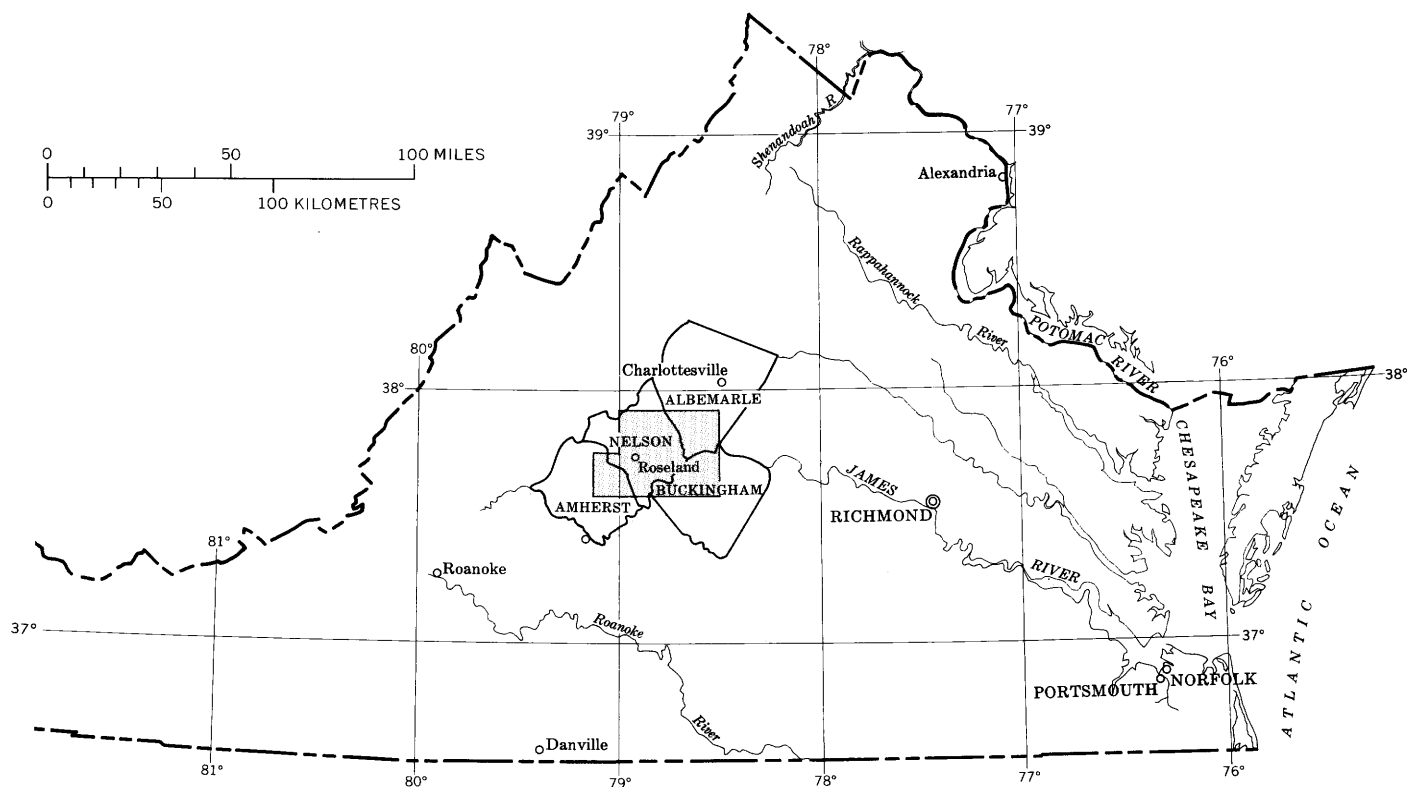


FIGURE 1.—Index map showing Nelson, Amherst, Albemarle, and Buckingham Counties, and Roseland, Va., the center of the central Virginia rutile district. Area covered by plate 1 is shaded.

ley and Ridge province. Titanium deposits are known to be associated with the Roseland Anorthosite, a northeast-trending body about 15 km long and 4 km wide (pl. 1). The anorthosite consists largely of light-bluish-gray megacrysts of andesine antiperthite that are cut by zones of cream to white granulated feldspar (Ross, 1941). Charnockitic and mafic rocks are present as dikes and irregular patches and lenses throughout the anorthosite body but are more abundant in the border zone (Herz and others, 1970, p. F3, F4). Quartz, where present, is blue. Titanium minerals are ilmenite and rutile, both rimmed by "leucoxene" (Ross, 1941).

Ilmenite and apatite are present in the border zone, chiefly in nelsonite dikes. Some varieties of these dikes are rich in rutile, magnetite, biotite, and hornblende, or are gabbroic. The dikes range in width from several centimetres to 20 m, and are as much as 600 m long (Watson and Taber, 1913, p. 101, 102). The dikes are younger than the anorthosite and are the source of the richest saprolite deposits of ilmenite (Fish and Swanson, 1964). At least one other formation in the area, the Pedlar of Bloomer and Werner (1955), also contains high percentages of ilmenite. The Pedlar Formation is a

coarse-grained porphyroblastic gneiss which locally contains relict hypersthene. Ilmenite averages 1.5 percent (R. O. Bloomer, written commun., May 1973) but may be as much as 8 percent and is rimmed by "leucoxene."

PHYSIOGRAPHY

A jumbled mass of mountains, which range in altitude from 600 to 1,200 m, trends from the northern part of the area westward and southward in an arc, nearly encircling a hilly erosional reentrant lowland of the headwaters of the Tye, Piney, and Buffalo Rivers. A series of northeast-trending linear ridges separates this intermontane hilly lowland from the James River valley in the southeast part of the area. Altitudes of these linear ridges range from 300 to 400 m. Altitudes of the hills within the mountain-locked lowland range from 250 to 300 m (pl. 1). The Roseland Anorthosite is a low plateau in the intermontane lowland; it has a relief of about 30 m.

After draining the intermontane lowland, the Tye and Piney Rivers and, later, the Buffalo River join as they flow through a narrow gorge cut through the linear ridges in the southeast, before joining the James River at Norwood. The Tye River descends

about 700 m in the study area. The Rockfish River flows northeast, then southeast, to join the James at Howardsville, 29 km downstream from Norwood (pl. 1). The Rockfish descends about 850 m from its headwaters. The James River follows a wandering northeast course through rolling country along the southeast boundary of the area; the gradient averages about 1 m/km.

The flood plain of the James River is as much as 1 km wide. The Tye River system has its widest flood plains on the anorthosite body, but they are mostly less than 400 m wide. The flood plain of the South Fork Rockfish River (in the upper Rockfish River Valley) is as much as 1 km wide.

Thick saprolite blankets much of the area, but bedrock outcrops are common on steeper slopes and along streams. Most of the mountain areas are forested; typically, the only cleared areas of any extent are in the lowlands and stream valleys.

PREVIOUS MINING ACTIVITIES

The earliest mining activity apparently was in 1878 when minor investigations were undertaken by the Philadelphia and Reading Coal and Iron Co. in its exploration for iron deposits. Some subsequent activity was directed towards investigation of the phosphate content in nelsonite. The next significant activity was by the American Rutile Co. in 1900, in the first attempt to mine rutile, largely from bedrock. In 1930, the Vanadium Co. of America began mining saprolite along the Piney River (Fish, 1962, p. 5). In 1944, these properties were acquired by the American Cyanamid Co., which mined titanium minerals in the saprolite at several places in the area until 1971. A more detailed history of mining has been given by Fish (1962), Fish and Swanson (1964), and Herz and others (1970).

PRESENT STUDY

The present study began as an outgrowth of that by Herz and others (1970). Herz and Minard planned the sampling of flood-plain deposits in and near Herz's study area in order to supplement his data. Sampling was done by Minard and Hayes, and analyses by Force and Hayes.

Although this study is supplemental to that by Herz and others (1970), it differs in several ways:

1. Most samples were obtained by augering below the ground surface of stream terraces and point bars, instead of by shoveling a 10-quart bucket full of bottom material from riffles in present stream channels.

2. The area of sample collection was increased to include downstream extensions of streams draining anorthosite and nearby streams not draining anorthosite. Large-volume deposits along the James River, which drains the entire area, were also sampled.
3. Hurricane Camille occurred in August 1969 (Virginia Division of Mineral Resources, 1969; Williams and Guy, 1973), after the sampling reported in Herz and others (1970) but before that done for this report. Flood waters associated with the hurricane locally deposited sediments containing high percentages of titanium oxides.
4. Analysis procedure has a different emphasis in this study. Size analyses were done on many samples in order to examine the influence of sorting on the heavy-mineral concentrations. Methylene iodide (specific gravity 3.3) was used as a separating medium in order to limit more closely the heavy fraction to minerals of economic interest (ilmenite and rutile); relatively little study of the mineralogy was done.
5. The number of samples collected was 260, as compared with 31 collected by Herz and others (1970).

Cross sections constructed along auger traverses and logs of individual holes are shown on plate 1. Percentages of heavy minerals, mostly ilmenite, are also shown for those samples analyzed.

FIELD METHODS

The method used in most of the sampling program was to auger a series of holes on a line of traverse across the flood plain, terrace, or point bar normal to the stream channel. Generally two to four holes were augered along each traverse line. From one to as many as five or six lines were traversed across each terrace or bar, depending on its length. In some places only one hole was augered, usually because of the small area of the terrace or bar, the shallow depth to bedrock, or because of obstacles such as ditches and crop cover which prevented access by the truck-mounted auger.

Each hole was augered to bedrock or, in some places, probably to a boulder layer. Samples were collected as channel samples from each 1.5-m auger length. The auger was rotated slowly to a depth of 1.5 m, rotation was stopped, and the auger was withdrawn from the hole. The outer surface of the material on the auger flight (spiral land) was scraped off, and the remaining material along the entire 1.5-m length was sampled continuously. The flight was

thoroughly cleaned, lowered in the hole until it touched bottom, another auger length added, rotation started, and penetration to 3 m achieved. Rotation was stopped, the auger string withdrawn from the hole, and the process repeated each 1.5 m or until further penetration was not possible. A truck-mounted power auger was used, having 1.5-m long auger lengths of 11-cm diameter in a continuous string (fig. 2A). Holes were dug by hand through surface cobble layers to enable augering below these layers (fig. 2B).



A



B

FIGURE 2.—A, Augering at cross section 27 across a point bar along the James River. About 2 m of the 3 m of exposed auger lengths contain a sample of silty sand. B, Hole dug through cobble layer so the auger could penetrate underlying pebbly sand. Contrast with silty sand of A. At cross section 15, South Fork Rockfish River.

LABORATORY METHODS

Although 260 samples were collected, only 148 were analyzed in the laboratory, and, of these, the

analyses for 122 are used in this study. Those samples consisting totally or largely of silt and clay generally were not analyzed, and some that were analyzed were not used. Some sample analyses were discarded because of faulty laboratory procedures.

Each sample analyzed was dried, and the clumps were disaggregated by a rubber roller to ensure a more correct size distribution. A 100–300-g split of the dried disaggregated sample was made for analysis. After being weighed, the sample was placed in a 62 μ screen and first shaken dry to remove loose silt and clay and then washed to remove any silt and clay coatings on the sand grains. Any remaining muddy coating of the sand grains was removed by immersing the washed sample, on the 62 μ sieve, into an ultrasonic cleaner for 15–20 minutes. No chemical removal of grain coatings was necessary for purposes of mineral identification.

The dried washed sample was again weighed, and the weight loss was entered as the silt and clay fraction. A RoTap¹ having 2-mm, 1-mm, 500 μ , 250 μ , 125 μ , and 62 μ screens (1 ϕ interval) was used to size-sort the sand and gravel. Each fraction was weighed, and heavy minerals were collected separately from the fractions.

Methylene iodide, having a specific gravity slightly less than 3.3, was used as the heavy liquid in separations (rather than bromoform, which has a specific gravity of about 2.9). This was to reduce the amount of noneconomic heavy minerals, especially sillimanite, hornblende, and biotite, in the concentrate. Separations were done in a gravity funnel for each size fraction. These fractions were washed with acetone, dried, and weighed.

For some samples, the minerals in the heavy fraction were separated and identified. Magnetite was removed from the concentrates by means of a hand magnet; further magnetic separations were made by using a Frantz isodynamic separator. Concentrates were separated on the Frantz at a final setting of 0.35 amperes (with forward and side slopes of 20°), after which they were weighed. To avoid loss of sample, amperage was progressively increased from 0.05 to 0.35 amperes on successive runs of the sample; the magnetic fraction of each run was caught in the same container. Magnetic separation at 0.35 amperes was done to separate the rutile and other minerals from the ilmenite. This amperage was determined experimentally and appears to be mostly successful (Herz and others, 1970, used the same value).

¹ Any trade names in this publication are used for descriptive purposes only and do not constitute endorsement by the U.S. Geological Survey.

For many samples, not all the above steps were necessary. The most common shortcut was to do heavy-mineral separations of only a few size fractions, which resulted in minimum heavy-mineral values. For many other samples, such as those for which no magnetic separation was done, complete analyses were not made.

AREAS SAMPLED

The first period of sampling was in June 1970, along the flood plain of the Tye River on the anorthosite body near its southern edge (pl. 1, table 1). Six point bars were sampled southeastward along the river to the town of Tye River. From here to Norwood, at the confluence of the Tye and the James River, only two small bars were sampled. This segment of the Tye River is mostly in a narrow gorge having very few bars, most of which are small (pl. 1). The river distance from the southern edge of the anorthosite body to Norwood is 32 km. Sampling was continued downstream along both sides of the James to beyond Scottsville, a river distance of about 53 km, a total distance of 85 km downstream from the anorthosite. Terraces and bars along the James River are many and large (pl. 1). During this period, 185 samples were collected; 177 were taken along the James and Tye Rivers. The remaining eight were collected from shallow holes near Wintergreen in the valley of the South Fork Rockfish River (pl. 1), 9 to 14 km north of the north end of the anorthosite body and in an entirely different drainage basin having no streams draining from the anorthosite. This was done to see if high values of titanium minerals were present in deposits derived from areas other than the known ilmenite- and rutile-bearing anorthosite body.

Seventy-five additional samples were obtained during March and April 1971; these were collected in scattered areas to fill in gaps from the earliest sampling. Of these samples, 10 more were collected near Wintergreen, and six additional sites were sampled along the James River above the confluence with the Tye River, instead of below it, as had been done earlier. This was done to compare detritus partly contributed from the Roseland district (via the Tye River) with that which came from the upper James River and was not in any part derived from Roseland.

Samples also were collected along the Buffalo River. These included detritus partly derived from the south end of the anorthosite body and some that had its source entirely outside the body. Surprising-

ly high percentages of ilmenite are present in terrace and bar deposits whose drainage has no contribution from the area of the anorthosite body. These areas are along the Buffalo River and Beaver Creek, at and above their junction 2 to 3 km southwest of the south end of the anorthosite body (pl. 1). A value of nearly 8 percent ilmenite was obtained from a bedrock outcrop here also (sample 510, table 1, fig. 3).

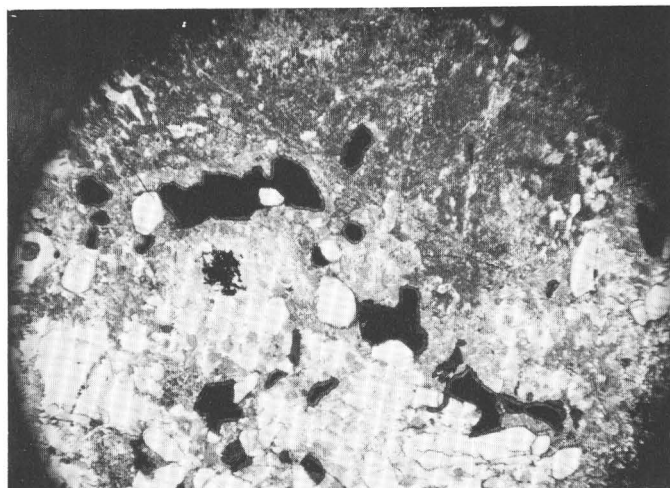


FIGURE 3.—Photomicrograph of dioritic ilmenite-rich facies of gneiss from the Pedlar Formation of Bloomer and Werner (1955) showing ilmenite (black) rimmed by sphene-anatase intergrowths. Plane light, X 20. Sample 510 from location of cross section 9 (table 1, pl. 1).

TYE RIVER

The Tye and Piney Rivers together drain most of the Roseland Anorthosite terrane, as well as an area of gneiss, some of which is altered granulite (Herz, 1968). No samples were collected from the Piney River valley for this study; 32 samples were collected and analyzed from the Tye River valley.

The areal extent of alluvial deposits and the distribution of samples in the Tye River valley are shown on plate 1 and in table 1. The total area of these deposits is 1.6 km². There are no alluvial deposits of appreciable areal extent in the Tye River valley downstream from the junction with Piney River. The samples collected from this area were mostly poorly sorted pebbly sands from small terrace deposits.

MINERALOGY

Ilmenite is predominant in the heavy-mineral concentrates of the Tye River samples (tables 2, 4). Rutile is also present but in varying and much lesser

TABLE 1.—Locations of samples and cross sections
[Hmc, heavy-mineral content]

Cross section	Sample No.	River valley	7½' quadrangle	Latitude	Longitude	Remarks
1----	478	Tye	Horseshoe Mountain.	37°45'45"	78°59'30"	
2----	314-321	do	Arrington	37°43'	78°58'52"	
3----	322-324	do	do	37°42'50"	78°58'52"	
4----	333-336	do	do	37°41'50"	78°58'20"	334 was horizontal channel sample 20 ft across surface of bar. Hmc, 71 percent.
5----	325-331	do	do	37°41'15"	78°57'40"	
6----	519-520	do	do	37°39'	78°57'23"	
7----	337-340	do	Shipman	37°40'45"	78°50'15"	
8----	341-343	do	do	37°40'40"	78°49'05"	
9----	506-513	Buffalo	Piney River	37°39'05"	79°06'15"	509 was sum of 2 horizontal channel samples across surface of stream bars; Hmc, 25 percent. 510 was sample of bedrock; Hmc, 8 percent. 511 was horizontal sample; Hmc, 29 percent.
10----	527	do	do	37°38'05"	79°03'50"	
11----	521-524	do	Amherst	37°36'40"	79°03'01"	523 and 524 were horizontal channel samples across stream bars. Hmc, 9 percent and 13 percent, respectively. Along Rutledge Creek near its confluence with Buffalo River.
12----	525-526	do	do	37°35'05"	79°00'23"	
13----	518	do	Buffalo Ridge	37°36'42"	78°55'05"	
14----	479	Rockfish	Horseshoe Mountain.	37°52'15"	78°54'57"	
15----	480-482	do	Sherando	37°52'52"	78°53'53"	
16----	503-504	do	Greenfield	37°53'15"	78°52'15"	
17----	483-484	do	do	37°53'37"	78°51'45"	
18----	485-486	do	Gladstone	37°35'08"	78°49'45"	
19----	514-516	James	Shipman	37°37'34"	78°49'20"	
20----	528-529	do	do	37°38'22"	78°48'38"	
21----	348-364	do	Shipman	37°38'40"	78°47'42"	
22----	365-372	do	do	37°38'40"	78°47'25"	
23----	373-383	do	do	37°38'25"	78°46'32"	
24----	387-396	do	do	37°38'15"	78°45'27"	
25----	397-401	do	Howardsville	37°38'15"	78°43'22"	
26----	402-410	do	do	37°39'53"	78°43'10"	
27----	423-435	do	do	37°40'06"	78°42'43"	427 was horizontal channel sample of loose surface sand on a narrow terrace near the river; Hmc > 20 percent.
28----	445-457	do	do	37°40'25"	78°42'40"	
29----	412-418	do	do	37°41'15"	78°41'33"	
30----	466-471	do	Esmont	37°45'30"	78°36'10"	
31----	488-493	do	Scottsville	37°45'22"	78°28'	Outside the area shown on plate 1.
Hole						
A----	344-347	James	Shipman	37°38'30"	78°48'30"	
B----	384-386	do	do	37°38'36"	78°47'08"	
C----	419-422	do	Howardsville	37°41'30"	78°41'41"	
D----	458-460	do	do	37°41'40"	78°39'06"	
E----	461-465	do	do	37°43'52"	78°38'45"	
F----	473-477	do	Esmont	37°45'50"	78°33'20"	
G----	494-495	do	Scottsville	37°45'20"	78°27'43"	Outside the area shown on plate 1.

amounts (Herz and others, 1970). In contrast to "ilmenite" from many placer mines, this ilmenite has a sharp pattern on an X-ray diffractometer and has a chemical composition (table 3) near that of sto-

ichiometric ilmenite. Ilmenite grains commonly are rimmed or veined by white fine-grained material ("leucoxene") which is poorly crystalline even to X-ray diffraction; it consists primarily of aluminous

TABLE 2.—*Mineralogy of heavy (sp gr > 3.3) fractions of samples from the Tye and James Rivers in order of distance downstream*

[Only 125 μ -250 μ -size fractions examined. Opaque minerals were separated magnetically; ilmenite separates were verified by X-ray diffractometer. A, abundant (>10 percent); C, common (1-10 percent); P, present (<1 percent)]

	Sample No.			
	317	339	374	426
Drainage -----	Tye River.	Tye River.	James River.	James River.
Cross section -----	2	7	22	27
Ilmenite (having "leucoxene" rims) (percent).	76	69	76	65
Magnetite (percent).	P	1	3	10
"Leucoxene" -----	A	A	C	C
Rutile -----	C	P	P	P
Epidote -----	C	C	C	A
Kyanite -----	C	P	C	P

TABLE 3.—*TiO₂ content of selected ilmenite separates*

[Frantz 0.15-0.35 amp fractions of methylene iodide concentrates from 60 μ -250 μ size fractions. Analyses by Leung Mei, U.S. Geological Survey]

Sample No.	Drainage	Percent TiO ₂ in ilmenite
323 -----	Tye River -----	51.7
343 -----	do -----	51.3
372 -----	James River -----	47.8
467 -----	do -----	45.6
481 -----	Rockfish River -----	48.9
513 -----	Buffalo River -----	52.0

sphene having subordinate anatase (M. L. Bird, oral commun., 1972). Cores of ilmenite grains are crystalline and probably are relatively unaltered. Rims of grains commonly are broken, abraded, or both, indicating that they formed before transport. Modern stream sediments here also contain rimmed ilmenite. Ross (1941, pls. 18, 19) shows rims of "sphene leucoxene" around ilmenite grains in fresh specimens of Roseland Anorthosite and nelsonite; rims also occur on ilmenite grains in some gneiss from the Pedlar Formation and other hypersthene-bearing rocks (fig. 3). Herz (1968, p. 365) regards these rims as the result of Paleozoic retrograde metamorphism.

Blue (rutilated; Ross, 1941) quartz is present in retrograded gneiss from the Pedlar Formation and in Roseland Anorthosite. It appears to be particularly abundant in the alluvial samples in which titanium minerals also are abundant and is believed to have been derived from the same sources. Locally, it makes a helpful prospecting tool for titanium minerals. Epidote is present in those samples gathered farthest downstream (va 341-3, 337-40) and indicates dilution by tributaries draining greenstone of the Catocin Formation.

HEAVY-MINERAL CONTENTS

Plate 1 and table 1 show the distribution and tenor of heavy minerals in alluvial deposits in the Tye River valley. Several deposits appear to have mineral concentrations high enough to be of economic interest. Volume of the deposits, however, is limited (table 4).

TABLE 4.—*Approximate ilmenite resources of some terrace deposits in the study area*

Drainage (river)	Cross sections and holes included (see pl. 1)	Approximate volume of terrace alluvium (m ³)	Average grade of heavy minerals (percent)	Ilmenite content of concentrate (percent)	Ilmenite resources (10 ⁴ tonnes)
Upper Tye --	2, 3	2 \times 10 ⁶	3.5	80	10
Lower Tye --	7, 8, A	1 \times 10 ⁶	2.0	70	3
Buffalo -----	9	1 \times 10 ⁶	3.0	80	7
James -----	27	3 \times 10 ⁶	2.5	65	10
(samples 423-432)					

Hurricane Camille, in August 1969, caused heavy damage in the Tye River valley and left flood-plain sand deposits that are markedly enriched in heavy minerals, compared with other Tye River valley deposits. Although the cause of the enrichment is not definitely known, the enrichment probably resulted from stripping of heavy-mineral-rich saprolites from the source rocks and erosion, reworking, and concentration of older Tye River valley deposits. All these processes were on a large scale (Virginia Division of Mineral Resources, 1969; Williams and Guy, 1973).

Samples from the Tye River valley show that some relationships exist among heavy-mineral concentrations, grain-size distribution, and distance downstream from source.

GRAIN SIZE

Grain sizes of most samples are shown in table 5. Figure 4 shows size-distribution histograms of different, but typical, samples that show several characteristics. Heavy minerals (specific gravity > 3.3) commonly are finer than the mode of the entire sample. Samples having the highest heavy-mineral concentrations have modes in the medium- to coarse-sand range.

Sorting is variable, and Trask sorting coefficients range from about 2 to 8 (precise values cannot be calculated because of the crudeness of the size separation). The heavy-mineral content seems to be weakly related to the sorting of the deposits (fig.

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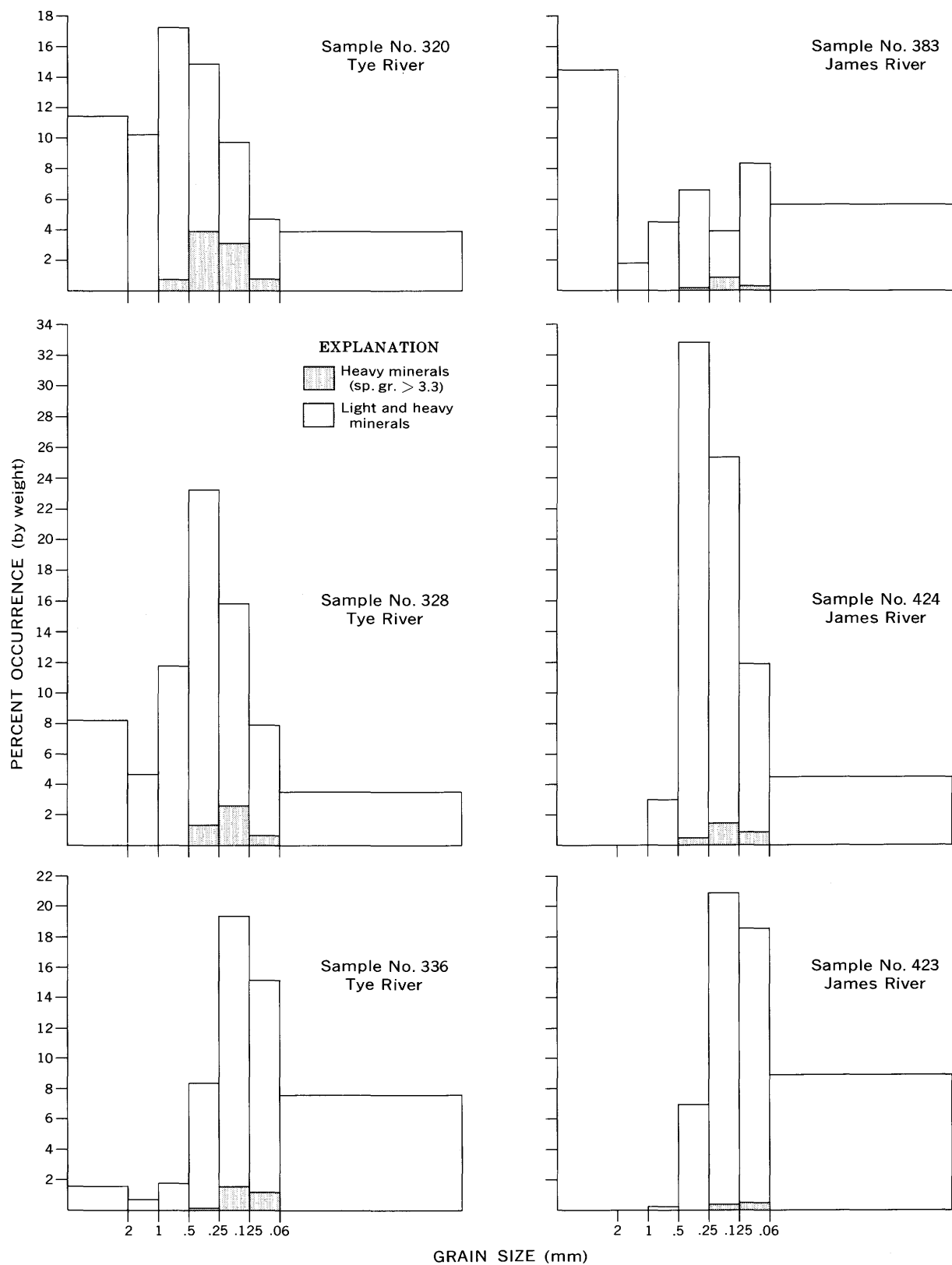


FIGURE 4.—Histograms showing grain sizes of some typical alluvial samples and their heavy minerals from Tye River and James River deposits. Gravel contents have arbitrarily been divided into two grades and mud contents into six grades.

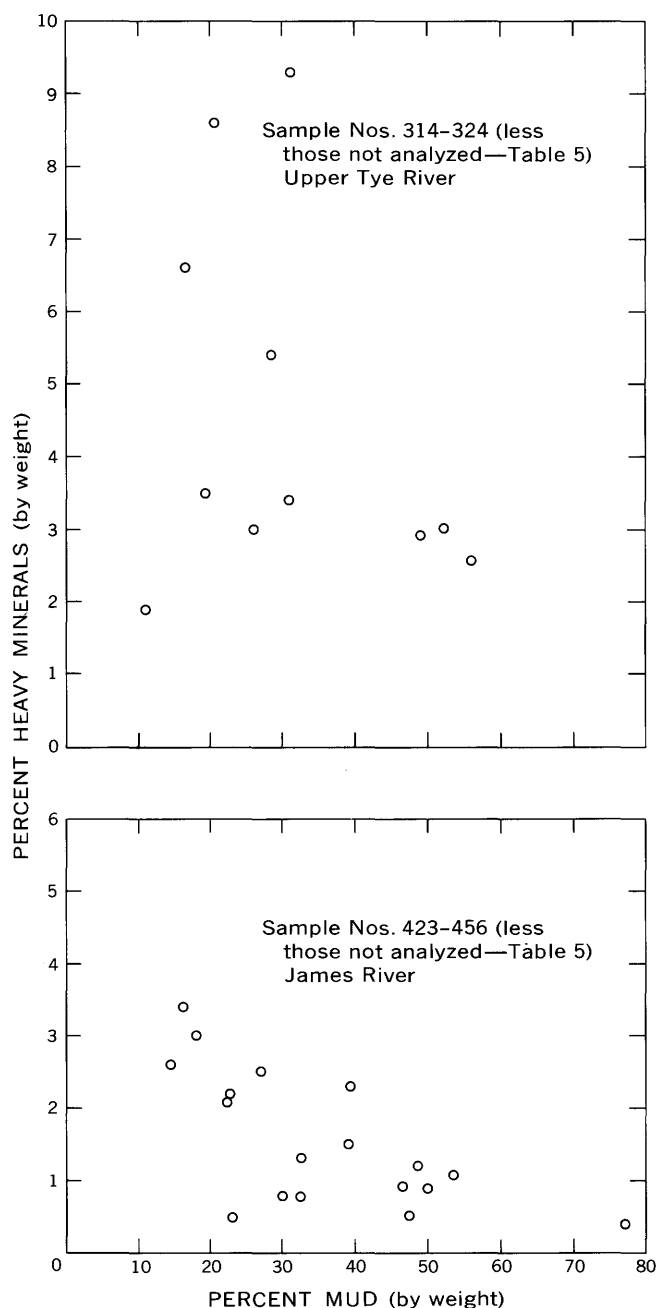


FIGURE 5.—Heavy-mineral and mud contents of some Tye River and James River samples. In each diagram, all samples are from one terrace.

5); however, this may be no more than a diluting effect of the amount of mud in the sample. Within a sample series from the same auger hole, the percentage of heavy minerals commonly increases as depth increases. This is apparently a consequence of lesser mud content at depth.

TRANSPORT DISTANCE

Among samples having a given modal grain size and mud content, heavy-mineral concentration is an inverse function of distance from the source. Figure 6 shows the downstream decrease in heavy-mineral

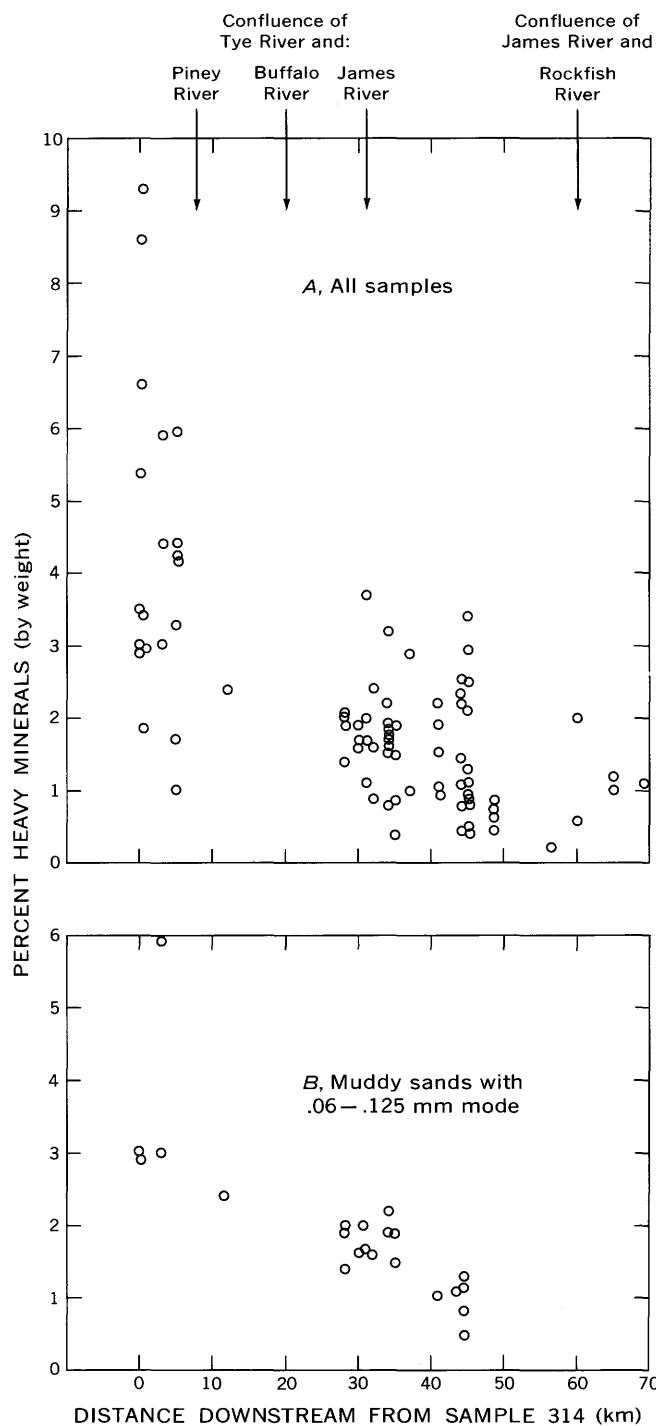


FIGURE 6.—Decrease in heavy-mineral content of Tye River and James River deposits as a function of increasing distance downstream from sample 314 (cross section 2).

TABLE 5.—Grain sizes (as determined by sieving) and heavy-mineral data for alluvial samples

[All percentages are rounded to the nearest whole number. Ilmenite defined by magnetic properties. A, averaged on plate 1; ?, questionable mode; n.d., not determined]

Sample No.	Percent gravel (>2 mm)	Percent sand (0.06 mm-2.0 mm)	Percent mud (<0.06 mm)	Modal interval (mm)	Percent heavy minerals (sp gr >3.3)	Modal interval heavy minerals (mm)	Percent ilmenite in heavy minerals	Percent ilmenite in total sample
314	0	47	53	0.125-0.25	3.0	?	n.d.	--
315	0	44	56	.06-.125	2.6	?	n.d.	--
316	1	50	49	.125-.25	2.9	?	n.d.	--
317	21	51	28	.125-.25	5.4	0.125-0.25	76	4.1
318	43	37	20	?	3.5	.125-.25	n.d.	--
319	11	58	31	.125-.25	9.3	.125-.25	86	8
320	23	56	21	.5-1	8.6	.25-.50	n.d.	--
321	30	54	16	.5-1	6.6	.25-.50	n.d.	--
322	22	52	26	.25-.5	3.0	?	80	2.4
323	4	65	31	.2-.5	3.4	?	82	2.8
324	28	61	11	.2-.5	1.9	?	82	1.6
325	2	62	36	.2-.5	3.3	?	77	2.5
326	2	77	21	.25-.5	1.7	?	n.d.	--
327	2	85	13	.25-.5	4.2	.125-.25	n.d.	--
328	16	63	21	.25-.5	4.4	.125-.25	n.d.	--
329	7	48	45	?	1.0	?	n.d.	--
330	3	70	27	.2-.5	4.2	?	78	3.3
331	22	59	19	.2-.5	6.0	?	n.d.	--
333	3	60	37	.25-.5	4.4	.125-.25	n.d.	--
334	0	96	4	.25-.5	71.0	.125-.25	n.d.	--
335	2	64	34	.125-.25	5.9	.125-.25	n.d.	--
336	3	51	46	.125-.25	3.0	.125-.25	n.d.	--
337	0	59	41	.125-.25	1.9	.125-.25	n.d.	--
338	0	69	31	.125-.25	1.4	?	n.d.	--
339	5	59	36	.125-.25	2.0	?	69	1.4
340	5	65	30	.125-.25	2.0	?	n.d.	--
341	0	48	52	?	1.9	?	71	1.3
342	0	43	57	?	1.7	?	70	1.2
343	7	49	44	?	1.7	?	73	1.2
344	0	45	55	.125-.25	2.0	?	n.d.	--
345	0	43	57	.125-.25	1.7	?	n.d.	--
346	0	38	62	.125-.25	1.1	?	n.d.	--
347	19	59	22	.5-1.0	3.7	.125-.25	n.d.	--
348	0	38	62	?	.9	?	67	.6
349	Muddy; not analyzed							
350	3	25	72	?	.6	?	65	.4
351, 352	Muddy; not analyzed							
353	0	43	57	?	1.0	?	64	.6
354	0	33	67	?	.8	?	n.d.	--
355	13	31	56	?	.8	?	n.d.	--
356-358	Muddy; not analyzed							
A 359	0	31	69	?	.4	?	n.d.	--
360	2	28	70	?	.5	?	n.d.	--
361, 362	Muddy; not analyzed							
363	5	30	65	?	.7	?	n.d.	--
364	11	37	52	?	.8	?	n.d.	--
365-367	Muddy; not analyzed							
368	1	36	63	?	.9	?	n.d.	--
369-370	Muddy; not analyzed							
371	0	54	46	.2-.5	1.6	?	n.d.	--
372	22	47	31	.2-.5	2.4	?	n.d.	--
373	0	43	57	.125-.25	2.2	?	n.d.	--
374	0	79	21	.25-.50	3.2	.125-.25	76	2.4
375	0	57	43	.25-.50	1.6	?	n.d.	--
376-378	Muddy; not analyzed							
379	33	32	35	.125-.25	.8	?	n.d.	--
380, 381	Muddy; not analyzed							
382	6	49	45	.125-.25	1.9	?	n.d.	--
383	29	36	35	Several modes	1.6	.125-.25	n.d.	--
384	Muddy; not analyzed							
A 385	0	79	21	.2-.5	1.7	?	n.d.	--
386	17	72	11	.2-.5	1.7	?	n.d.	--
387	Muddy; not analyzed							
388	0	56	44	-----	1.5	?	n.d.	--
389	1	70	29	.2-.5	1.9	?	n.d.	--
390, 391	Muddy; not analyzed							
392	3	35	62	-----	.9	?	n.d.	--
393-395	Muddy; not analyzed							
396	1	38	61	.125-.5	.4	?	n.d.	--
397	Muddy; not analyzed							
398	3	73	24	.2-.5	2.9	?	n.d.	--
399, 400	Muddy; not analyzed							
401	3	32	65	?	1.0	?	n.d.	--
402	Muddy; not analyzed							
403	0	65	35	.2-.5	1.9	?	n.d.	--
404	10	75	15	.2-.5	2.2	?	n.d.	--

TABLE 5.—Grain sizes (as determined by sieving) and heavy-mineral data for alluvial samples—Continued

Sample No.	Percent gravel (>2 mm)	Percent sand (0.06 mm-2.0 mm)	Percent mud (<0.06 mm)	Modal interval (mm)	Percent heavy minerals (sp gr >3.3)	Modal interval heavy minerals (mm)	Percent ilmenite in heavy minerals	Percent ilmenite in total sample
405 -----	26	60	14	0.2-0.5	1.5	?	n.d.	--
406 -----	Not analyzed							
407, 408 -----	Muddy; not analyzed							
A { 409 -----	2	46	52	.2-.5	1.0	?	n.d.	--
410 -----	32	41	27	.5-1	1.0	?	n.d.	--
412 -----	Not analyzed							
413 -----	0	43	57	?	.9	?	n.d.	--
414 -----	9	42	49	.2-.5	.8	?	n.d.	--
415-418 -----	Muddy; not analyzed							
419, 420 -----	Muddy; not analyzed							
421 -----	2	38	60	?	.7	?	n.d.	--
422 -----	16	28	56	?	.5	?	n.d.	--
423 -----	0	47	53	.125-.25	1.1	?	n.d.	--
424 -----	0	73	27	.25-.5	2.5	.125-.25	n.d.	--
425 -----	0	77	23	.25-.5	2.1	.125-.25	n.d.	--
426 -----	6	78	16	.25-.5	3.4	.125-.25	65	2.2
427 -----	Not analyzed							
428, 429 -----	Not analyzed							
430 -----	0	77	23	.2-.5	2.2	?	n.d.	--
A { 431 -----	2	80	18	.2-.5	3.0	?	n.d.	--
432 -----	5	80	15	.2-.5	2.6	?	n.d.	--
433, 434 -----	Muddy; not analyzed							
435 -----	24	53	23	.5-1	.5	?	n.d.	--
436-438 -----	Muddy; not analyzed							
A { 439 -----	10	51	39	.2-.5	2.3	?	n.d.	--
440 -----	16	45	39	.2-.5	1.5	?	n.d.	--
441, 442 -----	Muddy; not analyzed							
A { 443 -----	24	44	32	.2-.5	.8	?	n.d.	--
444 -----	23	47	30	.06-.2	.8	?	n.d.	--
445, 446 -----	Muddy; not analyzed							
A { 447 -----	0	54	46	?	.9	?	n.d.	--
448 -----	3	65	32	.2-.5	1.3	?	n.d.	--
449, 450 -----	Muddy; not analyzed							
A { 451 -----	4	47	49	?	1.2	?	n.d.	--
452 -----	7	43	50	?	.9	?	n.d.	--
453 -----	Muddy; not analyzed							
454 -----	0	23	77	?	.4	?	n.d.	--
455 -----	Muddy; not analyzed							
456 -----	0	53	47	?	.5	?	n.d.	--
457 -----	5	66	29	.2-.5	.8	?	n.d.	--
458, 459 -----	Muddy; not analyzed							
460 -----	48	21	31	?	.2	?	n.d.	--
461-463 -----	Muddy; not analyzed							
464 -----	0	34	66	?	.6	?	n.d.	--
465 -----	24	45	31	?	2.0	?	n.d.	--
466 -----	Muddy; not analyzed							
467 -----	3	34	63	?	1.0	?	65	.65
468-470 -----	Muddy; not analyzed							
471 -----	30	40	30	?	1.2	?	n.d.	--
473-476 -----	Muddy; not analyzed							
477 -----	7	40	53	?	1.1	?	n.d.	--
478 -----	5	28	67	.2-.5	1.4	?	n.d.	--
479 -----	Error in analysis							
480 -----	2	37	61	?	.7	?	77	.54
481 -----	34	36	30	.2-.5	2.4	?	75	1.8
482 -----	Error in analysis							
483 -----	55	23	22	Several modes	.8	?	n.d.	--
484 -----	Error in analysis							
485 -----	49	33	18	Several modes	2.2	?	n.d.	--
486 -----	34	25	41	?	1.4	?	n.d.	--
488, 489 -----	Muddy; not analyzed							
490 -----	18	22	60	?	.4	?	n.d.	--
491 -----	Muddy; not analyzed							
492 -----	Not analyzed							
493 -----	9	66	25	.2-.5	1.9	?	n.d.	--
494 -----	Muddy; not analyzed							
495 -----	2	46	52	?	1.1	?	n.d.	--
A { 503A -----	4	35	61	?	1.8	?	n.d.	--
503B -----	7	54	39	.2-.5	3.2	?	74	2.4
503C -----	56	39	5	?	1.9	?	84	1.6
503D, 503E -----	Error in analysis							
A { 504A -----	6	43	51	.2-.5	3.3	?	n.d.	--
504B -----	13	43	44	.2-.5	3.4	?	n.d.	--
504C -----	2	38	60	?	2.5	?	n.d.	--
506A -----	Muddy; not analyzed							
506B -----	19	35	46	.2-.5	1.2	?	n.d.	--
506C -----	28	39	33	.2-.5	4.1	?	n.d.	--
507A, 507B -----	Muddy; not analyzed							

TABLE 5.—*Grain sizes (as determined by sieving) and heavy-mineral data for alluvial samples—Continued*

Sample No.	Percent gravel (>2 mm)	Percent sand (0.06 mm-2.0 mm)	Percent mud (<0.06 mm)	Modal interval (mm)	Percent heavy minerals (sp gr >3.3)	Modal interval heavy minerals (mm)	Percent ilmenite in heavy minerals	Percent ilmenite in total sample
507C -----	Not analyzed							
508 -----	8	38	54	0.2-0.5	2.9	?	n.d.	--
¹ 509 -----	1	93	6	.2-.5	25.0	?	n.d.	--
510 -----	rock				8.0	?	n.d.	--
511A -----	0	40	60	?	1.2	?	n.d.	--
511B -----	31	64	5	.2-.5	15.4	?	n.d.	--
¹ 511C -----	40	57	3	.2-.5	29.0	?	n.d.	--
512A -----	3	43	54	?	3.1	?	n.d.	--
512B -----	18	68	14	.5-1	20.6	.2-.5	n.d.	--
513 -----	7	73	20	.2-.5	4.4	?	85	3.7
514A-514E -----	Muddy; not analyzed							
514F -----	Error in analysis							
515A, 515B -----	Muddy; not analyzed							
515C -----	Error in analysis							
515D -----	23	44	33	.2-.5	1.9	?	n.d.	--
516A-516C -----	Muddy; not analyzed							
516D -----	25	30	45	?	1.9	?	n.d.	--
518A -----	Muddy; not analyzed							
518B -----	12	50	38	.2-.5	1.8	?	n.d.	--
519A, 519B -----	Muddy; not analyzed							
519C -----	Not analyzed							
520A, 520B -----	Muddy; not analyzed							
520C -----	23	43	34	?	2.4	?	n.d.	--
521A, 521B -----	Muddy; not analyzed							
522A, 522B -----	Muddy; not analyzed							
522C -----	2	50	48	?	3.5	?	n.d.	--
522D -----	28	43	29	?	2.3	?	n.d.	--
¹ 523 -----	1	95	4	.2-.5	9.0	?	n.d.	--
¹ 524 -----	1	94	5	.2-.5	13.0	?	n.d.	--
525A, 525B -----	Not analyzed							
526A, 526B -----	Not analyzed							
527A -----	0	20	80	?	.8	?	n.d.	--
527B -----	0	51	49	.2-.5	3.7	?	n.d.	--
527C -----	5	74	21	.2-.5	8.7	?	n.d.	--
527D -----	15	57	28	.2-.5	8.0	?	n.d.	--
528A -----	Muddy; not analyzed							
528B, 528C -----	Not analyzed							
528D -----	1	74	25	.2-.5	1.5	?	n.d.	--
528E -----	12	75	13	.5-1	1.1	?	n.d.	--
529A, 529B -----	Muddy; not analyzed							
529C -----	39	18	43	?	.5	?	n.d.	--

¹ Channel sample

content in samples having nearly the same grain size characteristics. A few of the samples shown are from the James River, downstream from the mouth of the Tye River. The decrease probably is due primarily to dilution. Among the entering tributaries are the Piney River, having 18 percent of the drainage area of the entire Tye River system; Brown Creek, having 4 percent; the Buffalo River, having 36 percent; and Rucker Run, having 9 percent. The James River, at its junction with the Tye, has 11 times the drainage area of the Tye River. Of these streams, other than the upper Tye River, only the Piney and Buffalo Rivers drain anorthosite, and the Buffalo drains only a minor area of it. Clearly, dilution does not appear to be as rapid as would be expected if the anorthosite were the only major source of heavy minerals (predominantly ilmenite). Therefore, ilmenite probably is being contributed from other sources. In the following descriptions of drainage basins that contain no anorthosite, the contribu-

tion of heavy minerals by the gneisses of the Pedlar Formation are discussed.

BUFFALO RIVER AND SOUTH FORK ROCKFISH RIVER

Nineteen samples were collected along the Buffalo River, a tributary to the Tye River (pl. 1). The upstream samples (506-513) are from a part of the stream that drains no anorthosite. Gneisses, including those from the Pedlar Formation, are the predominant rocks in all the drainage areas. Valley deposits consist primarily of pebbly sands. The heavy-mineral concentrates from sediments sampled in the Buffalo River drainage basin, consist almost entirely of ilmenite (table 5), with some magnetite and zircon. Ilmenite is commonly rimmed with "leucoxene" as in the samples from the Tye River drainage area.

Plate 1 and table 5 show the distribution and grade of heavy minerals within the deposits of the Buffalo River valley. Generally, the percentage of heavy min-

erals is quite high. No relationship of heavy-mineral content to sorting was noted here. The highest group of values in samples 506–513 is believed to be related to influx from Beaver Creek; sediment presently being transported in the headwaters of Beaver Creek is black because of the high ilmenite content. The source rock here is the Pedlar Formation, which in this area contains abundant ilmenite rimmed with “leucoxene” (fig. 3); two analyzed samples of bed-rock each show 8 percent ilmenite.

The South Fork Rockfish River drains a small area of high relief north and east of the Roseland Anorthosite (pl. 1). No anorthosite is known to occur in the drainage area; the source rocks are gneiss, including gneiss of the Pedlar Formation, and the greenstone in the Catoclin Formation. Valley-bottom deposits are predominantly cobbly sands. Nine samples were analyzed from this area; heavy-mineral concentrates from these samples consist mostly of ilmenite (table 5). However, epidote is abundant in most concentrates; it was probably derived from weathering of greenstone. Ilmenite is rimmed by “leucoxene” as it is in the Tye River valley deposits.

Plate 1 and table 5 show the distribution and grade of heavy minerals within alluvial deposits of the South Fork Rockfish River. A few values are moderately high, but none is of particular economic interest when the cobbly nature and small volume of the sediment are considered. No significant relationship of heavy-mineral content to sorting was noted.

Nowhere in the drainage basins of the Buffalo River and South Fork Rockfish River are the alluvial deposits of sufficient volume to form an economically attractive deposit (table 4). The sediments are of interest in this study, however, because they are an example of ilmenite entering the system from non-anorthosite source areas. The conclusion reached in analyses of the Tye River samples, that the anorthosite is not the only major source of alluvial ilmenite in the area, is supported by samples taken from these streams. Gneiss of the Pedlar Formation and other hypersthene-bearing gneiss also appear to be significant sources of ilmenite in the study area.

JAMES RIVER

All the streams previously discussed are tributaries to the James River. By the time some of the waters of the James have arrived in the study area, they have passed through the Valley and Ridge and Blue Ridge provinces and have entered the Piedmont.

Alluvial deposits along the James River are of much larger volume than those found along the other

ivers, as discussed earlier in this report. Terrace flood-plain widths of 800 m and thicknesses of 5 m are common. Samples were collected over a river distance of 58 km, of which 6 km are upstream from the mouth of the Tye River. Sixty-nine samples from the James River were analyzed.

As is true in the samples previously discussed, ilmenite having rims of “leucoxene” is the predominant heavy mineral (tables 2, 4). Average TiO_2 content of ilmenite is lower than in the Tye River samples, probably because of the addition of ilmenite having iron oxide intergrowths (table 3). Also present as important constituents are magnetite and epidote. Biotite and frosted quartz grains are conspicuous among the light minerals. The presence of blue quartz in a sample rich in ilmenite was observed in only one sample (347), and this was from near the mouth of the Tye River, in which blue quartz is common in samples rich in ilmenite.

Plate 1 and table 5 show the distribution and grade of heavy minerals within alluvium along the James River. In general, concentrations of heavy minerals are less than 2.5 percent. Increase in heavy-mineral concentrations as depth below the surface of the ground increases, is evident at several sample sites. This in turn is again dependent on the grain-size distribution of the sample; the basal deposits are coarser, and the coarser fractions have higher concentrations of heavy minerals.

A few check samples were collected from bluffs along the James River downstream from Scottsville. These samples also show the lower average heavy-mineral values (table 6) characteristic of increased distance downstream. Ilmenite again is the predominant heavy mineral; rutile is minor in all samples except those from farthest downstream near Goochland, where it is also present in the local gneiss bedrock.

CONCLUSIONS

1. Small deposits of alluvium in the Tye River drainage basin have high percentages of ilmenite, whereas nearby large deposits along the James River have low percentages. Highest values occur in coarse mud-free deposits which most often were at the base of the alluvial deposits sampled during this study. Dilution occurs in a downstream direction and decreases both the proportion of the heavy-mineral concentrate in the samples and the value of the heavy-mineral concentrate by admixing magnetite and epidote. Exceptionally

TABLE 6.—Heavy-mineral content of alluvium exposed in James River bluffs downstream from Scottsville

[Separation from channel samples 1–3 m long. C, common; P, present; N, not detected.]

Distance downstream from Scottsville (km)	Locality description	Percent heavy-mineral (sp gr >3.3) content, predominantly ilmenite	Rutile in concentrate
23.1	Levee deposit (sand) -----	1.9	P
24.4	do -----	1.0	P
26.8	Flood-plain deposit (silty sand).	.3	N
28.1	Flood-plain(?) deposit (silty sand).	.2	P
33.0	Levee deposit (silty sand) ---	.3	P
37.0	Flood-plain deposit (sand) ---	2.3	N
39.4	Levee(?) deposit (sand) ----	.8	N
42.5	Flood-plain(?) deposit (silty sand).	.9	N
44.3	Flood-plain deposit (sand) --	1.4	P
45.9	Flood-plain deposit (silty sand).	1.1	P
48.9	Flood-plain(?) deposit (silty sand).	.5	N
52.6	Flood-plain(?) deposit (silty sand).	.4	N
53.5	Flood-plain(?) deposit (sand).	.5	P
54.7	Flood-plain deposit (sand) --	1.8	P
59.7	Flood-plain deposit (sand) --	.7	P
62.1	Flood-plain(?) deposit (silty sand).	.3	N
69.2	Flood-plain deposit (silty sand).	1.3	N
71.6	Flood-plain(?) deposit (silty sand).	.5	C
79.3	Flood-plain deposit (sand) --	1.5	C
81.5	Flood-plain deposit (silty sand).	.7	C

high values of titanium minerals shown in horizontal channel samples across present stream bars suggest that such deposits may be buried and easily missed by sparse sampling, but may be readily recoverable in standard mining operations.

- As this study began, our belief was that the Rose-land Anorthosite was the only major source for high-grade alluvial placer deposits of ilmenite in the area. However, when we discovered that hypersthene-bearing gneisses also were important contributors, the existence of additional ilmenite placers in the Blue Ridge seemed possible. Figure 7 shows the location of the source rocks in and near the study area.
- As redefined by this study, the area of the source rocks favorable for formation of ilmenite placers is at least 16.4 percent (746 km²) of the James River drainage at the downstream end of the study area. At Richmond, where the James River enters the Coastal Plain province, its drainage basin is 1.48 times as large as it is

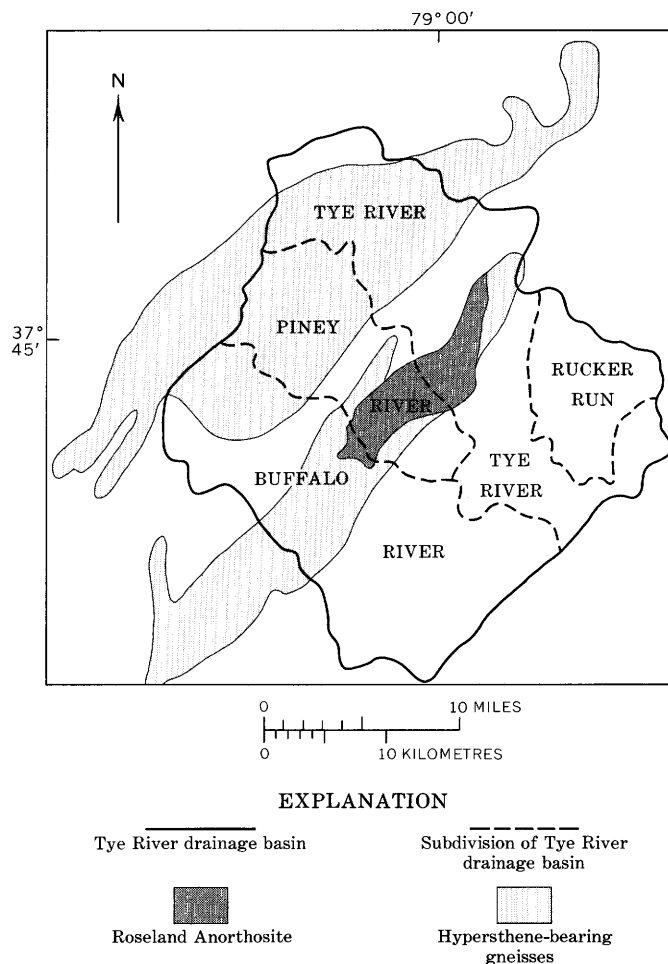


FIGURE 7.—Sketch map showing location of source rocks of ilmenite in the Tye River drainage basin. Rock boundaries generalized from Bloomer and Werner (1955) and Herz (1968).

in the study area. It seems plausible that titanium minerals may be present in economic concentrations in some of the Coastal Plain sediments.

Long-range plans include a sampling program that continues downstream along the James River and into the Coastal Plain. Sampling traverses will be made across the inner Coastal Plain to explore and attempt to locate possible areas where ilmenite placers may have been concentrated in tidal deltas or bars, or in beach ridges.

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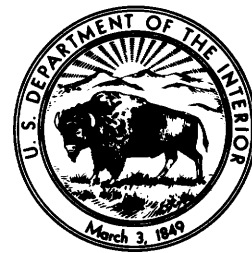
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