Rutile and Ilmenite Placer Deposits Roseland District, Nelson and Amherst Counties, Virginia

By NORMAN HERZ, L. E. VALENTINE, *and* E. R. IBERALL

CONTRIBUTIONS TO ECONOMIC GEOLOGY

GEOLOGICAL SURVEY BULLETIN 1312-F

Analyses of panned concentrates of heavy minerals from the Roseland district indicate the possibility of valuable placer deposits of titanium minerals

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1970

UNITED STATES DEPARTMENT OF THE INTERIOR

WALTER J. HICKEL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

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ABSTRACT

The Roseland district, Virginia, has long been one of America's leading producers of titanium minerals from both lode and saprolite deposits. Inasmuch as more than 20 million tons of saprolite ore is present in the area, it was concluded that placer deposits might have formed as a result of the winnowing of the saprolite by modern streams. To test this concept, 31 panned concentrates of heavy minerals were collected from alluvium in the Tye and Piney River drainage areas and analyzed for rutile, zircon, ilmenite, and magnetite. Rutile was found to be concentrated in the +40-mesh fraction, in which it averages 11.4 and 8.8 percent, respectively, in samples from the Tye and Piney River drainage areas. Ilmenite is abundant in all samples, from an average low in the Tye River area +200-mesh fraction of 53.7 percent to a high in the Piney River area +100-mesh fraction of 76.5 percent. Zircon is largely concentrated in the +200-mesh fraction, and magnetite is present and generally has a low concentration in all samples.

The results indicate the possibility of valuable placer deposits of titanium minerals in large flood-plain and other alluvial deposits in the Roseland area; they also indicate that further exploration is warranted to determine their grade and tonnage.

INTRODUCTION

The Roseland district of Nelson and Amherst Counties, Virginia, has long been one of the world's most important sources of the titanium minerals ilmenite and rutile. The district is in the west-central part of Virginia about midway between Charlottesville and Lynchburg in the Piney River and Massies Mill 7½-minute quadrangles and the Lovingston and Shipman 15-minute quadrangles (fig. 1). Mining in the area began in 1878 for iron, but it was apparently unsuccessful because the nature of the ilmenite ore was not understood (Watson and Taber, 1913, p. 47–50). Beginning in the early part of this century, however, both rutile and apatite were mined, and soon the American Rutile Co. was supplying the entire world demand for rutile. Mining of rutile continued until 1949 when it was discontinued because of competition from Australian beach placer deposits.

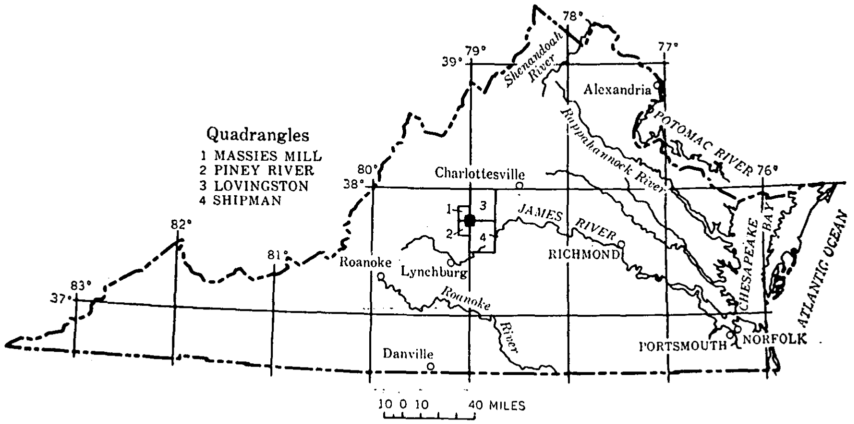

FIGURE 1.—Index map of Virginia showing the Roseland district (shown by solid area).

Saprolite [1] deposits containing ilmenite were first mined along the Piney River in 1930 by the Vanadium Corp. of America (Fish, 1962, p. 5). The properties of this company were acquired in 1944 by the American Cyanamid Co. to supply ilmenite for a new pigment plant at Piney River. Currently, American Cyanamid is the only active producer of titanium minerals in the district.

Ilmenite- and rutile-bearing saprolite deposits within only a small part of the area exceed 20 million tons and average 7.0 percent TiO_2 (Fish, 1962). Over the entire area, actual saprolite reserves must be several orders of magnitude greater than this figure. Considering the great abundance of easily recoverable titanium minerals in saprolite, perhaps even higher grade deposits may have been produced by the winnowing action of streams in the area. To test this possibility, W. C. Overstreet and Norman Herz made a reconnaissance study of the district in March 1968, and 31 panned concentrates were collected from streams draining the area.

Heavy liquid and magnetic separation, screen analysis, and X-ray and petrographic analyses were carried out on the panned concentrates at a U.S. Geological Survey laboratory in Washington, D.C.

Splits of the heavy-mineral concentrates were analyzed by the Division of Mineral Resources, Commonwealth of Virginia Department of Conservation and Economic Development, Charlottesville, Va., using X-ray emission for TiO_2 and atomic absorption for iron, manganese, zinc, and chromium. We are indebted to Dr. James L. Calver, Commissioner of Mineral Resources and Virginia State Geologist, for making the results of these analyses available for this report.

[1] "A general name for thoroughly decomposed, earthy, but untransported rock." (Am. Geol. Inst., 1960 p. 255.)

U.S. Geological Survey laboratories in Denver, Colo., analyzed splits of six samples by semiquantitative spectrographic methods.

The conclusion of the study is that valuable placer deposits of ilmenite and rutile may be present in the Roseland district, and that further exploration of flood-plain deposits is warranted to determine their grade and tonnage.

This study was carried out as part of a comprehensive research program authorized by the Office of Emergency Planning and undertaken by the Department of the Interior under the Defense Production Act for the purpose of developing a domestic source of rutile.

GENERAL GEOLOGY

The titanium deposits are associated with a northeast-trending anorthosite body about 8 miles long and 2½ miles wide, which parallels the trend of Precambrian Piedmont structural features. This body is in or near the core of the Catoctin Mountain-Blue Ridge anticlinorium (a series of recumbent folds, overturned to the northwest and trending northeast) and is part of the Virginia Blue Ridge complex of Brown (1958). The anticlinorium is bounded to the southeast by the "Martic Line" and the James River synclinorium of younger Precambrian and lower Paleozoic(?) rocks (Brown, 1953). The northwest limb of the anticlinorium contains upper Precambrian and lower Paleozoic formations (Werner, 1966).

The Virginia Blue Ridge complex in the Roseland area is made up primarily of schists, granites, charnockites, gneisses, anorthosite and its associated rocks, and migmatites. The country rock gneisses are well foliated, medium to coarse grained, and porphyritic in places; they are composed largely of feldspar, quartz, and biotite, and contain some ilmenite, muscovite, and hornblende (Watson and Taber, 1913, p. 201). Bloomer and Werner (1955) divided the gneisses into two units—the Lovingston Gneiss (contains large feldspathic augen) and the Marshall Gneiss (lacks conspicuous augen).

Hypersthene granodiorite, more correctly termed "charnockite," underlies much of the northwestern part of the Blue Ridge anticlinorium (Jonas, 1935) in Virginia and is either massive or layered in this area (Hillhouse, 1960). The layered variety is far more abundant and consists of alternating mafic-rich and quartz-feldspar-rich layers that average 10 centimeters in thickness. Fresh samples are composed of andesine antiperthite, microcline, andesine-oligoclase, quartz, and hypersthene.

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 occur as dikes and irregular patches and lenses throughout the anorthosite body, but they are most abundant in its border zone. The border zone consists of charnockitic rocks and interlayered charnockite, anorthosite, mafic rocks, and gneiss; it ranges in width from 0 to about 1.6 miles but averages less than 0.6 mile, except on the southwest border of the anorthosite body (fig. 2) where it is wider.

Nelsonite dikes, which consist essentially of ilmenite and apatite, are most abundant within the border zone (Watson and Tabor, 1913, p. 101). Some varieties of these nelsonite dikes are rich in rutile, magnetite, biotite, hornblende, or gabbro. The dikes range in width from a few inches to as much as 65 feet or more, and are as much as 2,000 feet long (Watson and Taber, 1913, p. 102). The dikes are younger than the anorthosite and its associated mafic rocks and are the source of the richest saprolite deposits of ilmenite (Fish and Swanson, 1964).

Apatite in the nelsonite is the fluorapatite variety and contains abundant cerium (700 ppm) and lanthanum (700 ppm) and elements of their rare-earth groups (Herz, 1969).

METHODS OF STUDY

The central and eastern parts of the anorthosite body are drained by the Tye River and its tributaries, especially Hat Creek and Jennys Creek (pl. 1). The western part of the anorthosite is drained by the Piney River and its tributaries, especially Allen Creek and Maple Run. Fifteen samples of stream alluvium were collected from the Tye River drainage system, including three on Hat Creek and five on Jennys Creek; and 16 from the Piney River system, including five on Allen Creek and three on Maple Run. One sample was obtained on Piney River 1.7 miles below its junction with Tye River (table 1).

The samples were taken from the upper 6–12 inches of riffles and bars in the beds of the streams. The riffle sand or gravel was shoveled wet into a 10-quart bucket (0.34 cu ft), and at each sample locality the bucket was filled so that the same volume of alluvium was always collected. The full sample was poured from the bucket through a sieve made of punch plate with ⅛-inch openings. Alluvium passing through the sieve was caught in a 16-inch prospector's pan and then shaken to make a concentrate. Later, in the laboratory, the dried concentrate was weighed (table 2). Heavy-mineral recovery by panning of riffle samples has been estimated as follows: Ilmenite, 64 percent; magnetite, 59 percent; rutile, 68 percent; and zircon, 72 percent (Theobald, 1957, p. 21). The total weight of the panned concentrates and the percentages of the recovered heavy minerals may thus be used to obtain qualitative data on the tenors of streambed materials; also, in conjunction with a study of aerial photographs, these data can be used to estimate lengths and widths of flood-plain

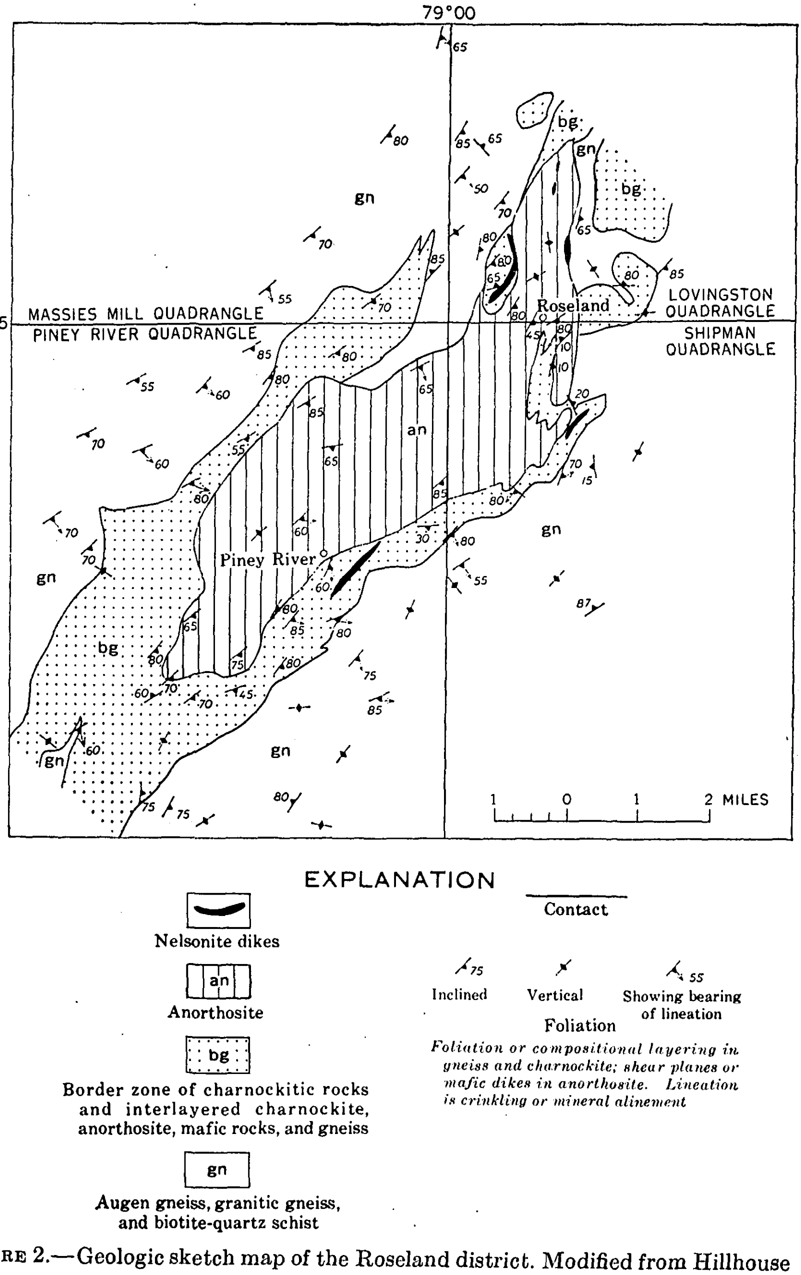

FIGURE 2.—Geologic sketch map of the Roseland district. Modified from Hillhouse (1960) and Herz (1969).

deposits and to identify areas where detailed sampling and drilling is justified (Overstreet and others, 1968).

In the laboratory the samples were first weighed dry and then sieved using standard sieve sizes of 40, 100, and 200 mesh. The light minerals were separated from each sieve fraction with bromoform (sp gr 2.86). A hand magnet was passed through the heavy minerals to remove the magnetite, and then the heavy minerals were passed through a Frantz isodynamic separator to remove and concentrate ilmenite. The remaining nonmagnetic heavy fraction was examined with a binocular microscope to determine the mineral assemblage and was then X-rayed. Percentages of rutile and zircon were calculated from the X-ray data, and percentages of magnetite and ilmenite were calculated from the two magnetic separates (table 2).

RESULTS OF MINERALOGICAL ANALYSIS

Both table 2 and plate 1 show that all samples are enriched in ilmenite and that the greatest amounts of heavy minerals are concentrated in stream deposits in two general areas—(1) the northeast border zone of the anorthosite body and (2) the southeast border zone of the anorthosite. A slight increase in total heavy-mineral content of stream deposits has also taken place in a southeasterly direction, which coincides with the major drainage direction. However, samples 194 and 195—about 2 and 4 miles, respectively, from the downstream contact of the anorthosite body—have a noticably lower content of heavy minerals than the samples in the contact area (table 2). This relation suggests that the heavy minerals have either remained close to their source or that physical changes, such as narrow valleys and high stream gradient downstream from the contact, have prevented deposition of large amounts of heavy minerals in these areas.

Average mineral abundances and standard deviations for rutile, zircon, ilmenite, and magnetite are given in table 3 and are summarized below.

RUTILE

Rutile is strongly concentrated in the +40-mesh fraction, which implies that it is close to its source, inasmuch as the mineral is rather brittle and would have been further comminuted if it had been transported far. Average abundances are higher in the Tye River drainage area than in the Piney, but by far the greatest amounts of rutile are found in the Jennys Creek-Allen Creek area. Surprisingly, the Tye River south of Roseland does not have anomalously high amounts of rutile even though it drains the area of the old Roseland rutile mine. Rutile has been found at the Buffalo quarry near sample 184, in a mafic dike in anorthosite. From these data, it is apparent that the most important rutile mineralization is in the southern part of the anorthosite body, probably in dikes similar to the one in the Buffalo quarry; the mineral also occurs as disseminations in anorthosite.

ZIRCON

Zircon is strongly concentrated in the +200-mesh fraction and does not appear to have been transported far. It is more abundant in the Tye River drainage area than in the Piney. In samples that contain the greatest amount of heavy minerals, the percentage of zircon is generally low. The average zircon content for concentrates in the >1,000-gram class is 1.4 percent; in the 400- to 999-gram class, 4.4 percent; in the 100- to 399-gram class, 3.9 percent; and in the <99-gram class, 3.9 percent. This size distribution suggests that most of the zircon is derived from schists and gneisses outside the anorthosite. Where large amounts of rutile and ilmenite were contributed by anorthosite and related rocks, the absolute amount of zircon has remained the same; but the percentage of zircon has consequently decreased.

ILMENITE

Ilmenite makes up more than half the average content of all sieve fractions but it is most abundant in the +100-mesh fraction. Its abundance in every sample suggests that ilmenite-bearing rocks are widespread throughout the area. The source of large volumes of ilmenite in saprolite deposits has been assumed to be nelsonite dikes (Fish and Swanson, 1964), and these dikes may possibly be much more abundant than is presently known. As contrasted with rutile and zircon, ilmenite is somewhat more abundant in the Piney River drainage area than in the Tye River drainage area.

MAGNETITE

Magnetite shows no systematic distribution according to grain size, but its abundance bears an inverse relationship to the abundance of ilmenite. Except for sample 193, magnetite reaches its greatest abundance in concentrates from the Tye River drainage area. The local abundance of magnetite in the northern part of the anorthosite body, as well as its occurrence along the southeastern contact zone, is here interpreted to indicate that magnetite is derived largely from rock types associated with the anorthosite.

RESULTS OF CHEMICAL ANALYSIS

The results of analysis for some major and minor elements are given in tables 4 and 5.

Gold content in six concentrates was determined in a U.S. Geological Survey laboratory by both atomic absorption and fire assay; it was found to be below 0.05 ppm in all samples.

Chevkinite, a titanosilicate of the cerium metals, is reported to have been found as an isolated 20-pound mass on Hat Creek, near Massies

Mill (Ford, 1932, p. 691). Ross (1941, p. 15) reported sphalerite in a small vein in Allen Creek half a mile southwest of Rose Union associated with quartz, pyrite, scarce galena, and a cobalt- and manganese-bearing clay (with a CoO content of 1.51 percent and an MnO+O content of 8.28 percent) that fills joint cracks in a nelsonite body mined by the Southern Minerals Corp. None of these mineral occurrences could be corroborated by X-ray analysis of the panned concentrates, although nearby samples do have high Zn (table 4).

SUGGESTIONS FOR FURTHER WORK

The information obtained in this study on detrital ilmenite and rutile in stream placers in the Roseland district is considered to be only qualitative until more complete data are obtained on the volume and tenor of available alluvium. The data do not define commercial placers. It is a well-known characteristic of stream deposits that the concentration of heavy minerals in active riffle sediments tends to be greater than the concentration through the full sequence of flood-plain alluvium from grass roots to bedrock. The work does show, however, that these heavy minerals are abundant in riffle gravel and that valuable deposits may have been created by stream action in the Roseland district. Such deposits seem likely to consist largely of ilmenite, but, in places, rutile is also rather abundant. To fully evaluate the available resources of ilmenite and rutile, churn drilling and detailed mapping in stream valleys will have to be carried out to determine the actual area, volume, and tenor of the deposits; the depth to bedrock; and the nature of the alluvial material.

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TABLE 1.—*Location and description of stream-placer samples, Roseland district, Virginia*

[Samples collected by W. C. Overstreet and Norman Herz, March 1968. See fig. 3 for sample location]

Sample	Quadrangle	Description
		TYE RIVER DRAINAGE
		Tye River
174	Massies Mill	North of anorthosite contact and just downstream from Cub Creek, 1.2 miles south of Tyro. River flowing swiftly over boulders, 8- to 20-in. in diameter common; sparse trails of black sand. Sample dug between boulders.
173	Lovingston	1 mile upstream from Lanes Ford. Gravel as much as 4 in. in diameter, in riffle.
172	do	State Route 156, 2 miles southeast of Massies Mill. Very swift flowing stream; cobble-boulder riffle that contains boulders as much as 18 in. in diameter. Sample contained cobbles as much as 7 in. in diameter.
		Hat Creek
175	Lovingston	0.3 mile east of Bryant. Riffle gravel, maximum diameter 5 in. Abundant black sand in 5-ft-wide streambed. Petrographic examination of the +100-mesh fraction by J. W. Whitlow shows (1) nonmagnetic fraction—rutile, fluorescent zircon, dark-gray to black ilmenite with many grains having a light-colored leucoxene alteration product; 20 percent light-colored fragments with

TABLE 1.—*Location and description of stream-placer samples, Roseland district, Virginia*—Continued

Sample	Quadrangle	Description
		TYE RIVER DRAINAGE—Continued
		Hat Creek—Continued
		darker cores (apatite?); traces of mica, sulfides, hematite, green mineral (not epidote); and questionable tantalite-columbite; (2) magnetic fraction—magnetite and traces of ilmenite.
176	Lovingston	East branch, 0.6 mile south of Shaeffer Hollow. Gravel as much as 5 in. in diameter. Stream 2½ ft wide. Black sand common on bed between cobbles.
177	do	0.8 mile southwest of Shaeffer Hollow road. Riffle gravel as much as 3 in. in diameter. Sand in stream rich in ilmenite and light-yellowish-green apatite.
		Tye River
170	Shipman	Near American Rutile Co. quarry at Roseland. Sample taken of riffle gravel at outside edge of river. Cobbles and boulders as much as 15 in. in diameter; sample contains cobbles as much as 5 in. in diameter.
171	do	Same locality as for sample 170 but in slough that has a fast current and 3-in. diameter cobbles.
		Petrographic examination of the +100-mesh fraction by J. W. Whitlow shows; (1) nonmagnetic fraction—fluorescent zircon, rutile, gray to black ilmenite that has a light-colored leucoxene alteration product; traces of hematite, epidote, garnet; an unidentified mineral; and questionable traces of monazite, xenotime, and staurolite; (2) magnetic fraction—magnetite and trace of ilmenite.
169	do	Gaging station at State Route 158. Cobbles and small boulders as much as 14 in. in diameter; sample is riffle gravel as much as 4 in. in diameter. Black sand trails downstream from cobbles.
		Jennys Creek
181	Piney River	East branch, 2 ft wide, 0.3 mile west-southwest of Hendersons Store. Gravel has maximum diameter of 2 in., on gray clay botton.
182	do	West branch, 3 ft wide, 0.5 mile east of St. James Church. Gravel has maximum diameter of 3 in., on a clay bottom.

TABLE 1.—*Location and description of stream-placer samples, Roseland district, Virginia*—Continued

Sample	Quadrangle	Description
		TYE RIVER DRAINAGE—Continued
		Jennys Creek—Continued
180	Piney River	West branch, 1½ ft wide, at State Route 151. Maximum diameter of riffle gravel is 3 in. No black sand streaks.
178	Shipman	Stream width 5 ft, at State Route 151. Maximum diameter of gravel is 5 in. in stream, in sample, 3 in. Black sand abundant in bed.
179	do	Small western tributary 3 ft wide near Rose Union Church on State Route 151. Gravel has maximum diameter of 4 in.; abundant black sand. Crenulated epidote-chlorite schist outcrop that contains quartz stringers.
		Tye River
194	Shipman	2 miles southeast of Roses Mill. Streambed contains cobbles to small boulders that have a maximum diameter of about 8 in.; in sample, 3 in. No visible black sand.
		PINEY RIVER DRAINAGE
		Piney River
188	Massies Mill	At Woodson. River is a mountain torrent that has a bed of large boulders as much as 2–3 ft across. Gravel sample, taken from downstream side of a boulder, contained cobbles as much as 6 in. in diameter.
187	Piney River	At Lowesville, downstream from bridge. Mixture of gravel, sand, silt, and muck taken from backwater area within rock outcrops and in rapids. Gravel as much as 1¼ in. in diameter.
199	do	Indian Creek at State Route 778. Stream about 12 ft wide flowing on gravel and sand. Abundant black sand. Gravel as much as 7 in. in diameter; in sample, as much as 5 in. in diameter.
		Petrographic examination of the +100-mesh fraction by J. W. Whitlow shows nonmagnetic fraction—fluorescent zircon, brownish-dark-gray to black ilmenite fragments that have "weathered" coating of leucoxene, and a few rutile fragments (some dark mineral fragments seem

TABLE 1.—*Location and description of stream-placer samples, Roseland district, Virginia*—Continued

Sample	Quadrangle	Description
PINEY RIVER DRAINAGE—Continued		
Piney River—Continued		
		soft and have a patina similar to cassiterite, whereas others are hard and brittle and have shiny fractures); traces of hematite, monazite or xenotime, sillimanite or actinolite, questionable tantalite-columbite, and other unidentified minerals were also found. The +200-mesh fraction contains fluorescent zircon, largely pink but some clear; ilmenite; questionable traces of monazite, sphene, and epidote; and traces of unidentified gray-brown to black minerals.
186	Piney River	Unnamed tributary, about 1.3 miles east of Lowesville. Stream, 1–2½ ft wide, flows on gravel and sand overlying gray clay. Sample from gravel that has maximum diameter of about 4 in. No black sand streaks.
189	do	At Old Dominion quarry. Sample is contaminated with anorthosite fragments and dust from crushed rock operations. Gravelly sand has maximum diameter of ¾ in.
190	do	At gaging station on State Route 151. Abundant coarse sand-size quartz and feldspar grains from Old Dominion plant. Maximum diameter of gravel in sample is 3½ in.
Allen Creek		
183	Piney River	East branch, east fork, 0.8 miles west of St. James Church. Creek flowing on outcrops of anorthosite and bed contains gravel as much as 1½ in. in diameter.
184	Piney River	East branch, west fork. Stream 2–7 ft wide flows on gravel that has a diameter of 4 in., sand and clay. No black sand streaks.
192	do	East branch at State Route 151. Stream flow is sluggish; sample contains gravel that has a maximum diameter of 4 in. and an abundant red sand matrix. No black sand streaks.
185	do	West branch at State Route 676. Stream about 1 ft wide flowing on clay that contains sparse gravel as much as 1½ in. in diameter. No black sand streaks.
191	do	West branch at State Route 151. Stream about 1½ ft wide, flowing sluggishly. Cobbles and small boulders as much as 8 in. in diameter, on gray

TABLE 1.—*Location and description of stream-placer samples, Roseland district, Virginia*—Continued

Sample	Quadrangle	Description
		PINEY RIVER DRAINAGE—Continued
		Allen Creek—Continued
		clay. Sample has cobbles as much as 5 in. in diameter. No black sand streaks.
		Maple Run
198	Piney River	At State Route 778. Steam about 3½ ft wide flowing over gravelly sand that has a maximum diameter of about ¾ in. Abundant black sand streaks.
197	do	At State Route 665. Sluggish stream about 4 ft wide flowing on gravelly sand that has a maximum diameter of 1½ in. Abundant black sand in streambed.
196	do	At State Route 151. Stream about 4½ ft wide flowing on cobble gravel that has a maximum diameter of 2 in. Abundant black sand in streambed.
193	Shipman	At Allen Creek-Piney River Junction (Roses Mill). Industrial waste from pigment plant causes red stain on pebbles and fine-grained black precipitate, possibly an iron sulfide, on streambed. Riffle gravel as much as 11 in. in diameter. Sample has abundant contaminant and gravel as much as 6 in. in diameter. Petrographic examination of the +40-mesh fraction by J. W. Whitlow shows ilmenite, magnetite, light-colored silicate(?) minerals, and rutile; traces of fluorescent zircon, tantalite-columbite, monazite, xenotime, sulfides, mica, garnet(?) kyanite(?), and other minerals. The +100-mesh fraction is largely magnetic with magnetite and ilmenite; many fragments have an overgrowth that appears siliceous; and traces of other mineral were also found.
		TYE-PINEY RIVER COMBINED DRAINAGE
195	Shipman	In Tye River below U.S. Route 29. River dammed about 600 ft downstream from highway bridge. Riffle gravel as much as 7 in. in diameter below dam (dam and flooded area not shown on pl. 1). Gravel sample as much as 3 in. in diameter. Red stain from industrial waste on pebbles.

TABLE 2.—*Results of analysis of heavy-mineral concentrates in stream-placer samples, Roseland district, Virginia*

Sample	Total weight of heavy-mineral concentrate (grams) (1)	Sieve size (mesh) (2)	Heavy-mineral content of sieve fraction (weight percent of col. 1) (3)	Mineral content (weight percent of heavy-mineral content of col. 3) (4)			
				Rutile	Zircon	Ilmenite	Magnetite
TYE RIVER DRAINAGE							
Tye River							
174	47.40	+100	83	2	1	73	2
		+200	17	2	9	68	4
Total concentrate			100	2	2.4	72.2	2.3
173	46.95	+100	94	2	1	70	2
		+200	6	2	4	63	3
Total concentrate			100	2	1.2	69.6	2.1
172	75.91	+40	76	10	2	34	8
		+100	22	5	4	45	3
		+200	2	2	5	53	4
Total concentrate			100	8.7	2.5	36.8	6.8
Hat Creek							
175	1,008.72	+40	42	10	1	73	7
		+100	55	3	2	72	4
		+200	3	2	27	53	4
Total concentrate			100	5.9	2.3	71.9	5.5
176	1,008.94	+40	52	6	0	82	4
		+100	45	1	2	83	4
		+200	3	<1	8	77	8
Total concentrate			100	3.6	1.1	82.3	5.0
177	580.01	+40	26	9	<1	66	20
		+100	70	5	9	73	4
		+200	4	3	21	57	3
Total concentrate			100	6.0	7.2	70.5	8.1
Tye River							
170	409.53	+40	15	7	<1	73	14
		+100	82	2	4	70	13
		+200	3	2	15	61	9
Total concentrate			100	2.8	3.7	70.2	13.0
171	430.37	+40	12	5	0	76	15
		+100	86	2	4	76	9
		+200	2	2	17	59	6
Total concentrate			100	2.4	3.8	75.7	9.7
169	1,066.46	+40	11	16	0	61	11
		+100	85	5	3	61	16
		+200	4	2	19	54	19
Total concentrate			100	6.1	3.3	60.7	15.6

TABLE 2.—*Results of analysis of heavy-mineral concentrates in stream-placer samples, Roseland district, Virginia*—Continued

Sample	Total weight of heavy-mineral concentrate (grams) (1)	Sieve size (mesh) (2)	Heavy-mineral content of sieve fraction (weight percent of col. 1) (3)	Mineral content (weight percent of heavy-mineral content of col. 3) (4) Rutile	Zircon	Ilmenite	Magnetite
Jennys Creek							
181	194.65	+40	23.5	17	3	70	3
		+100	68.5	5	10	65	1
		+200	8	3	39	41	1
Total concentrate			100	7.7	10.7	64.3	1.5
182	165.36	+40	21	14	1	75	3
		+100	72	2	7	73	1
		+200	7	3	49	33	1
Total concentrate			99	4.6	8.4	70.9	2.0
180	258.56	+40	100	20	0	60	1
		+100	39	3	9	65	5
		+200	3	3	45	10	28
Total concentrate			100	12.9	4.7	60.6	3.3
178	1,077.43	+40	85	9	1	59	8
		+100	14	6	1	62	19
		+200	1	2	4	59	26
Total concentrate			100	8.5	0.2	59.4	9.7
179	376.27	+40	54	14	<1	75	1
		+100	44	8	1	74	7
		+200	2	2	4	54	22
Total concentrate			100	11.1	0.5	74.2	4.0
Tye River							
194	220.93	+100	95	2	5	79	<1
		+200	5	2	17	63	3
Total concentrate			100	2.0	5.6	78.3	0.1
PINEY RIVER DRAINAGE							
Piney River							
188	169.40	+100	94	<1	2	91	1
		+200	6	1	16	71	4
Total concentrate			100	0.5	2.9	89.7	1.2
187	71.97	+100	82	2	2	85	2
		+200	18	1	14	65	3
Total concentrate			100	1.8	4.2	81.3	2.2
199	815.47	+40	6	5	3	87	3
		+100	90	1	3	88	<1
		+200	4	1	15	77	1
Total concentrate			100	1.2	3.5	87.5	0.3
186	81.97	+100	95	1	8	54	<1
		+200	5	0	37	33	<1
Total concentrate			100	1.0	9.4	53.0	<1

TABLE 2.—*Results of analysis of heavy-mineral concentrates in stream-placer samples, Roseland district, Virginia*—Continued

Sample	Total weight of heavy-mineral concentrate (grams) (1)	Sieve size (mesh) (2)	Heavy-mineral content of sieve fraction (weight percent of col. 1) (3)	Mineral content (weight percent of heavy-mineral content of col. 3) (4) Rutile	Zircon	Ilmenite	Magnetite
PINEY RIVER DRAINAGE—Continued							
Piney River—Continued							
189	202.62	+40	2	6	0	25	2
		+100	75	<1	3	83	<1
		+200	23	2	17	66	1
Total concentrate			100	1.2	6.2	77.9	0.3
190	147.50	+40	9	15	0	59	11
		+100	83	2	1	83	1
		+200	8	2	14	57	1
Total concentrate			100	3.1	2.0	78.9	1.9
Allen Creek							
183	111.92	+40	8	6	<1	88	3
		+100	89	2	3	68	4
		+200	3	1	26	57	12
Total concentrate			100	2.3	3.4	69.3	4.1
184	142.57	+40	9	5	1	90	1
		+100	85	1	<1	81	<1
		+200	6	2	4	65	<1
Total concentrate			100	1.4	0.4	80.8	0.1
192	330.74	+40	23	15	<1	76	<1
		+100	75	1	2	77	<1
		+200	2	<1	28	38	3
Total concentrate			100	4.2	2.0	76.1	<.1
185	174.45	+40	61	6	1	86	5
		+100	37	4	3	80	<1
		+200	2	3	15	48	<1
Total concentrate			100	5.2	2.0	83.0	3.0
191	1,539.95	+40	84	23	0	63	<1
		+100	15	10	2	77	3
		+200	<1	4	14	57	6
Total concentrate			100	20.9	0.4	65.1	0.5
Maple Run							
198	654.84	+40	7	4	<1	83	1
		+100	83	3	2	77	5
		+200	10	2	15	61	11
Total concentrate			100	3.0	3.2	75.8	5.3
197	1,751.25	+40	41	2	0	67	10
		+100	57	1	<1	80	8
		+200	2	1	4	67	10
Total concentrate			100	1.4	<0.1	74.5	8.9
196	1,992.64	+40	35	17	1	68	3
		+100	63	3	5	83	2
		+200	2	1	13	78	3
Total concentrate			100	8.0	3.8	77.7	2.4

TABLE 2.—*Results of analysis of heavy-mineral concentrates in stream-placer samples, Roseland district, Virginia*—Continued

Sample	Total weight of heavy-mineral concentrate (grams) (1)	Sieve size (mesh) (2)	Heavy-mineral content of sieve fraction (weight percent of col. 1) (3)	Mineral content (weight percent of heavy-mineral content of col. 3) (4) Rutile	Zircon	Ilmenite	Magnetite
PINEY RIVER DRAINAGE—Continued							
Piney River							
193	1,306.75	+40	59	2	0	60	14
		+100	39	1	1	40	35
		+200	2	<1	1	22	17
Total concentrate			100	1.6	0.4	59.0	29.0
TYE-PINEY RIVERS COMBINED DRAINAGE							
195	261.18	+40	15	9	0	47	21
		+100	82	2	2	58	26
		+200	3	<1	10	38	23
Total concentrate			100	3.0	1.9	55.8	25.2

TABLE 3.—*Mean weight percents (M) and standard deviations (sd) for rutile, zircon, ilmenite, and magnetite in heavy-mineral concentrates in each sieve fraction by drainage area, Roseland district, Virginia*

Screen size	Rutile		Zircon		Ilmenite		Magnetite	
	M	sd	M	sd	M	sd	M	sd
Tye River drainage area								
+40	11.42	4.52	0.75	0.88	67.00	12.09	7.92	5.80
+100	3.53	1.93	4.20	3.06	69.40	8.75	6.03	5.55
+200	2.17	0.62	18.87	14.51	53.67	15.37	9.40	9.08
Piney River drainage area [1]								
+40	8.83	6.54	0.63	0.82	71.00	17.72	4.50	4.40
+100	2.20	2.31	2.53	1.85	76.47	12.90	4.27	8.48
+200	1.47	1.01	15.53	9.02	57.47	15.50	4.90	5.01

[1] Magnetite: Without sample 193 (table 2), +40-M=3.64, sd=3.49; +100-M=2.07, sd=2.16; and +200-M=4.04, sd=3.96.

TABLE 4.—*Results of X-ray emission spectrographic analysis (for titanium) and atomic absorption analysis (for other elements) of heavy-mineral concentrates from stream-placer samples, Roseland district, Virginia*

[Analysts: Oliver M. Fordham, Jr., and Richard S. Good, Virginia Division of Mineral Resources, Charlottesville, Va. X-ray emission method: General Electric Co. unit, model XRD-5, tungsten target tube. Pelletized samples used. Atomic absorption method: Techtron unit, model AA-4, aceytlene flame]

Sample	Ti as TiO_2	Fe	Mn	Cr	Cu	Ni	Pb	Zn
	Percent			Parts per million				
TYE RIVER DRAINAGE								
Tye River								
174	47.4	31.9	1.16	79	13	13	48	630
173	47.7	30.6	1.23	65	15	19	58	650
172	46.7	28.9	1.06	115	16	15	55	480
Hat Creek								
175	44.5	25.9	1.10	153	10	15	25	360
176	49.8	31.5	.74	331	10.	16	24	270
177	49.1	27.3	1.09	224	11	12	40	320
Tye River								
170	48.1	29.3	1.13	145	10	16	43	390
171	48.7	31.2	1.08	171	8	16	33	410
169	49.7	31.0	1.10	203	8	18	41	430
Jennys Creek								
181	47.1	23.7	1.35	145	10	14	80	490
182	47.8	24.7	1.43	133	10	17	68	530
180	50.5	23.9	1.44	159	9	16	91	460
178	52.3	29.6	.70	580	12	19	30	240
179	50.0	28.7	.98	279	11	18	30	280
Tye River								
194	51.3	28.1	1.41	227	11	16	223	650
PINEY RIVER DRAINAGE								
Piney River								
188	49.7	30.8	1.36	38	10	9	41	890
187	49.4	29.4	1.33	65	12	20	53	710
199	48.6	29.4	1.42	27	8	13	33	760
186	50.8	26.1	1.88	178	17	17	88	860
189	47.2	28.5	1.32	49	23	17	103	890
190	45.6	28.7	1.30	61	21	14	76	640
Allen Creek								
183	51.4	27.0	1.84	142	18	21	83	1,210
184	49.0	26.6	1.51	97	15	17	87	870
192	52.7	26.4	1.56	170	13	16	61	890
185	48.6	25.9	1.57	158	19	29	119	860
191	50.6	25.9	1.24	230	10	20	85	400

TABLE 4.—*Results of X-ray emission spectrographic analysis (for titanium) and atomic absorption analysis (for other elements) of heavy-mineral concentrates from stream-placer samples, Roseland district, Virginia*—Continued

Sample	Ti as TiO_2	Fe	Mn	Cr	Cu	Ni	Pb	Zn
	Percent			Parts per million				
Maple Run								
198	49. 7	28. 0	1. 25	202	10	18	76	330
197	49. 0	29. 6	. 86	160	13	20	38	170
196	49. 5	29. 8	. 96	192	9	22	43	270
Piney River								
193	37. 5	28. 2	0. 54	233	22	27	58	240
195	45. 9	31. 3	. 72	268	17	20	39	380

NOTE.—Dilution factor of 0.5-g sample: Fe=10^4; Mn=10^4; Cr=10^2; Cu=10^2; Ni=10^2; Pb=10^2; Zn=10^2.

TABLE 5.—*Results of semiquantitative spectrographic analysis of six selected samples of heavy-mineral concentrates from stream-placer deposits, Roseland district, Virginia*

[Analyst: Harriet Neiman, U.S. Geological Survey. Au content determined by Claude Huffman, Jr., and W. D. Goss, U.S. Geological Survey, by fire assay and atomic absorption and found to be <0.05 ppm in all samples]

Element	Sample 175	178	188	194	198	199
Percent						
Si	1. 5	1. 0	1. 0	1. 0	1. 0	1. 5
Al	1. 5	. 7	. 7	. 7	. 7	. 7
Mg	. 3	. 3	. 1	. 15	. 2	. 05
Ca	1. 5	. 3	. 3	. 7	. 2	. 2
Mn	1. 0	. 5	1. 0	1. 0	1. 0	1. 0
Parts per million						
Ba	200	70	70	100	100	200
Co	20	30	10	15	15	20
Cr	200	500	50	200	200	20
Cu	<10	<15	<10	<10	<10	<10
Ga	10	10	10	15	10	15
Hf	≤200	200	200	200	≤200	≤200
Mo	<3	<3	15	<3	<3	15
Nb	150	150	700	300	150	500
Ni	7	7	2	5	3	<5
Pb	10	<10	10	10	70	<10
Sc	15	20	30	20	20	20
Sr	100	20	20	50	50	30
V	300	700	300	500	500	200
Y	70	<10	30	30	70	30
Zr	15, 000	1, 500	5, 000	7, 000	5, 000	7, 000

NOTE.—In all samples the following elements were looked for, but not found, as they were below sensitivity limits (given in parentheses in parts per million):

Na (500), K (7,000), P (2,000), Ag (0.5), As (1,000), Au (20), B (20), Be (1), Bi (10), Cd (20), Ce (150), Eu (100), Ge (10), In (20), La (30), Li (50), Pd (1), Pt (30), Re (30), Sb (150), Sn (10), Ta (200), Te (2,000), Th (200) Tl (50), U (500), W (100), Zn (500). In samples 175 and 198 the following were also looked for, but were below detection limits (given in parentheses in parts per million): Gd (50), Tb (300), Dy (50), Ho (20), Er (50), Tm (20), Lu (30).

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