Selected fluvial monazite deposits in the southeastern United States

by

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This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature

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Farther southwest in Georgia, around Griffin and Zebullon, along streams tributary to the Flint River in the monazite belt the flood plains are generally small and discontinuous, and only about 1 percent of the sediment is gravel. The area between Griffin, Zebullon, and the Flint River is underlain by biotite schist and biotite gneiss into which biotite granite has been intruded. Only along one stream, Flat Creek, which drains monazite-bearing granite near Zetella, Ga., are the tenors in monazite even moderately high, but a combination of thick, clayey overburden and discontinuous flood plains make the stream unsuitable for placer mining. Elsewhere in the Flint River area the heavy-mineral concentrates contain less than 1 percent monazite.

The southwesternmost area in which reconnaissance of the monazite belt was conducted includes a groups of southwest-flowing tributaries to the Chattahoochee River north of Pine Mountain and near La Grange, Ga. A combination of three characteristics of the alluvium make the area unfavorable for mining: (1) the upper half of the sedimentary sequence is clay and silt, (2) there is scant gravel, and (3) much of the sand is fine grained. Monazite is associated with the Snelson Granite, schists, and gneisses north of the Towaliga fault, but even in this area the tenor of most riffle sediments is only 0.1 to 0.5 pound of monazite per cubic yard, and the average tenor of the alluvium is about 0.2 pound per cubic yard. Rocks south of the Towaliga fault contain scant monazite. The monazite-bearing area in the drainage basin of the Chattahoochee River has no monazite placers.

Evidence from the areas on the Flint and Chattahoochee Rivers shows that streams in western Georgia are a much poorer source of monazite than streams farther to the northeast in Georgia, South Carolina, and North Carolina. Also, the northeastern part of the belt in the drainage basins of the Yadkin and Dan Rivers is a poorer source for monazite than the area between the Savannah and Catawba Rivers, S.C.-N.C.

Monazite-bearing crystalline rocks in the western belt contain about 0.06 pound of monazite per cubic yard. Residual soil derived from the crystalline rocks contains about 0.3 to 0.4 pound of monazite per cubic yard, and colluvial sediments formed by sheet-wash from saprolite, residual soil, and, rarely, old stream deposits, have an average of 3.1 pounds of monazite to the cubic yard. The data on the tenors of residual and colluvial deposits are far less comprehensive than those on the quantity of monazite in the crystalline rocks, but the tenors are probably of the correct order of magnitude. Neither the crystalline rocks nor the residual soils are ores of monazite. Because the colluvial deposits are thin and have patch distribution they could not be mined independently, but some colluvium could be stripped from the adjoining hills in conjunction with the mining of alluvial deposits in the valleys.

It is most unlikely that alluvial monazite placers have formed in the trunk streams leading southeastward out of the monazite belt. Churn drilling on the Broad and North Tyger Rivers, South Carolina, at the east edge of the belt has shown that the bulk of the alluvium is fine-grained sediment that contains 0.2 to 0.4 pound of monazite per cubic yard--tenors that represent no considerable enrichment over those in the crystalline rocks and residual soils. The probable persistence of predominantly fine-grained alluvium downstream to the Coastal Plain and the certain dilution of monazite-bearing concentrates by the inflow of monazite-free suites of heavy minerals between the belt and the fall line suggest that the trunk streams east of the belt are the least favorable sources for alluvial monazite in the Piedmont.

Introduction

Reconnaissance studies of the western monazite belt in the southeastern United States included examinations of four areas along the strike of the belt, in addition to the area between the Savannah and Catawba Rivers (Overstreet and others, 1968). One area is northeast of the Catawba River at the boundary between North Carolina and Virginia, and three are in Georgia southwest of the Savannah River (fig. 1). This division of the belt into five areas was an expedient designed to facilitate wide

Figure 1.--NEAR HERE

geographic sampling; it should not be inferred that monazite is restricted to the five areas in its distribution along the strike. Across the strike the outer margins of the monazite-bearing rocks are close to the northwestern and southeastern boundaries of the areas.

The four areas beyond the Savannah and Catawba Rivers lie in the drainage basins of the following trunk streams: (1) the Yadkin and Dan Rivers, N.C. and Va.; (2) the Oconee River, Ga.; (3) the Flint River, Ga.; and (4) the Chattahoochee River, Ga. None of the areas occupies the entire drainage basin of the trunk stream but only those parts that are in the monazite belt. For all practical purposes the amount of monazite available in streams tributary to the Yadkin and Dan Rivers and in the drainage basin of the Flint and Chattahoochee Rivers is negligible.

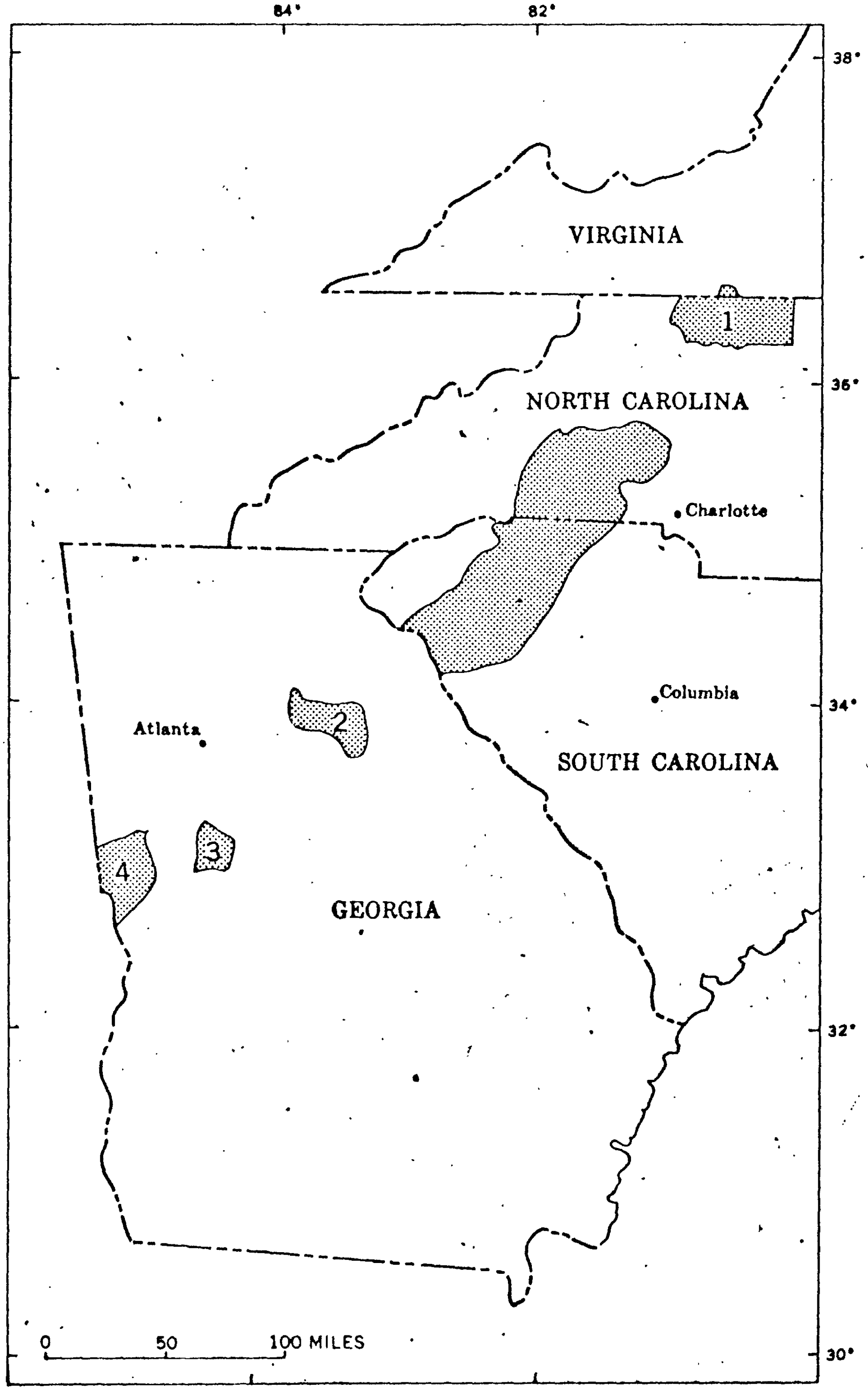

Figure 1.--Index map showing location of the four areas covered by this report. (1) Yadkin River-Dan River area, N. C.-Va.; (2) Oconee River area, Ga.; (3) Flint River area, Ga.; (4) Chattahoochee River area, Ga. Large stippled area is the area between the Savannah and Catawba Rivers, S. C.-N. C. (Overstreet and others, 1968).

Though the streams examined along the Oconee River are better sources of detrital monazite than those in the other three localities, these streams are not comparable in size, amount of gravel, or quantity of monazite with streams in the core of the belt in North and South Carolina. For these reasons the four areas beyond the Savannah and Catawba Rivers are given only short discussions in the following text.

Also introduced are summaries of the available data on deposits of monazite in bedrock, eluvial monazite placers, and alluvial placers in the trunk streams. None of these deposits was a primary object of study during reconnaissance, and none is a likely environment for monazite mining.

This work was part of a regional study done on behalf of the Division of Raw Materials of the U.S. Atomic Energy Commission; fieldwork leading to this report began in 1952 and ended in 1954.

Deposits between the Yadkin and Dan Rivers, North Carolina and Virginia

The area between the Yadkin and Dan Rivers comprises parts of Surry County and Stokes County, N.C., and Patrick County, Va. The Yadkin River heads in Watauga County, N.C., and flows east 45 miles to form the south boundary of Surry County. From the southeast corner of Surry County the Yadkin River flows toward the south and southeast to Lake Norwood. Between Lake Norwood and the Atlantic Ocean the stream is called the Pee Dee River. The Dan River rises in Patrick County, Va., and flows 20 miles to enter the area. It passes southeastward across Stokes County, N.C., thence flows northeastward into Virginia where it joins the Roanoke River.

Rocks of lower metamorphic rank than those between the Savannah and Catawba Rivers underlie the area between the Yadkin and Dan Rivers. Biotite schist, muscovite schist, and biotite gneiss are common, but pegmatite is less abundant than it is in the areas to the south. In northwestern Stokes County, N.C., hornblende gneiss is common. The schists are folded into an asymmetrical, northeast-trending syncline which has its steeper limb along the northwest. A large body of granite is intruded into the schists around Mount Airy. Pilot Mountain, Sauratown Mountain, and Hanging Rock are quartzite ridges which stand above the surrounding Piedmont surface. Relief increases to the north and northwest as the Blue Ridge is approached.

Most of the area is moderately populated and is extensively farmed. Mount Airy, the largest town, is served by a railroad, and a close net of roads gives access to most of Surry County and Stokes County.

Alluvium

South- and southeast-flowing streams that empty into the Yadkin River drain most of the area. Chief among these are the Mitchell, Fisher, and Ararat Rivers in Surry County and Patrick County. Drainage to the Dan River consists of a few short, east- and southeast-flowing tributaries, the largest of which is Big Creek in Stokes County.

The Mitchell, Fisher, and Ararat Rivers flow normal to the axis of the large syncline; thus they cut across the major planar structure of the metamorphic rocks. Their headwater tributaries generally follow down the dip of the steeper western limb of the syncline. Minor offsets in the courses of the tributaries follow the strike of the rocks and ultimately lead to the junction of the tributaries with the main streams. In the downstream part of the Mitchell River and in the middle and lower reaches of the Fisher and Ararat Rivers, the tributaries generally flow parallel to the axis of the syncline, with minor turns across the structure.

Flood plains between the Yadkin and Dan Rivers are commonly small and discontinuous. Most of the small streams have scant alluvium along flood plains that are only a few hundred feet in length and 100-400 feet in width. In general the better developed flood plains are along upstream parts of the larger streams. The best developed flood plains are along Stewarts Creek and the Little Fisher River. One of these, along the Little Fisher River 7.5 miles west of Mount Airy, is about 3.8 miles long and has an average width of 800 feet. Flood plains are narrow in, or absent from, the middle and lower parts of the Fisher and Ararat Rivers.

Logs of auger drill holes sunk in the Yadkin River and Dan River drainage basins are shown in tables 1 and 2. Flood plains drilled

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Tables 1 and 2.--NEAR HERE

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along tributaries to the Yadkin River (section A-A' through F-F') average 10.5 feet in depth of alluvium, and those drilled along the Yadkin River (sections G-G' and H-H') average 21.8 feet. Four holes (sections I-I' and J-J') sunk near the head of Big Creek, a tributary to the Dan River, show an average of 7.8 feet of alluvium in upstream flood plains.

/See pl. 1/

Section	Hole	Depth (ft)	Description of sediment. Terms are those defined in Overstreet and others, 1968, p. 52-53.
Stewarts Creek			
A-A'	D491	0-4	Yellow-brown silty clay
		4-10	Light-brown medium-fine sand, grades to coarse sand at 5, grades to sandy pebble gravel, sand coarse, at 7½
		10-14	Green-brown biotite schist saprolite
	D492	0-5	Gray-brown micaceous clayey silt
		5-9	Gray-brown sandy pebble-cobble gravel
		9	Blue-green biotite schist saprolite
	D493	0-5	Yellow-brown micaceous silt, grades to gray-brown micaceous sandy silt, sand fine, at 3
		5-8	Brown sandy pebble-cobble gravel, sand coarse
		8-9	Gray-brown biotite schist saprolite, unweathered biotite schist at base
B-B'	D490	0-5½	Gray and yellow-brown micaceous silty fine sand
		5½-6½	Brown pebbly coarse sand
		6½-9	Brown biotite schist saprolite

Table 1. Drilling data, Yadkin River drainage basin, Surry County, N.C.--

continued

Section	Hole	Depth (ft)	Description of sediment
B-B' cont.	D488	0-½	Dark-brown micaceous silt
		½-3½	Yellow-brown micaceous clayey silt
		3½-4½	Dark-blue-gray micaceous carbonaceous clayey silt
		4½-7½	Dark-brown pebbly sand
		7½-9	Yellow-brown biotite schist saprolite
	D489	0-4	Light-yellow-brown micaceous silty medium-fine sand
		4-10½	Gray-white pebbly coarse sand, grades to pebble gravel at 7
		10½-14	Yellow-brown biotite schist saprolite
C-C'	D485	0-2½	Dark-brown micaceous sandy silt, sand fine
		2½-5½	Greenish-gray micaceous sandy silt, sand fine
		5½-8	Black gravelly medium-coarse sand, grades to sandy pebble gravel at 7
		8-9	Yellow-brown biotite schist saprolite
	D486	0-8½	Brown micaceous silt, grades to silty medium sand at 3½, grades to pebble gravel at 5, grades to pebble-cobble gravel at 7
		8½-9	Yellow-brown biotite schist saprolite

Table 1. Drilling data, Yadkin River drainage basin, Surry County, N.C.--continued

Section	Hole	Depth (ft)	Description of Sediment
C-C' cont.	D487	0-3	Brown silt
		3-4½	Light-brown medium-fine sand
		4½-11	Dark-gray micaceous carbonaceous medium-fine sand, grades to coarse sand at 7, grades to sandy pebble gravel, sand coarse, at 8, grades to pebble-cobble gravel at 10
		11-12½	Biotite schist saprolite
D-D'	D494	0-2½	Yellow-brown gravelly clay
		2½-4	Gray micaceous carbonaceous silty clay
		4-10	Gray-brown micaceous sandy silt, sand fine
		10-13	Dark-gray micaceous carbonaceous clayey silt, gravelly at base
		13-14	Granite saprolite, unweathered granite at base
	D495	0-5	Micaceous sandy silt, sand fine, upper 3 ft yellow-brown grades to gray
		5-9	Gray medium sand and peaty clay
		9-13	Dark-gray pebble-cobble gravel
		13-14	Gray-white granite saprolite, unweathered granite at base

continued

Section	Hole	Depth (ft)	Description of sediment
D-D' cont.	D496	0-6	Light-brown micaceous silt
		6-6½	Light-brown medium sand
		6½-10	Gray and brown micaceous silty fine sand
		10-13½	Yellow-brown pebble-cobble gravel
		13½-14	Yellow to white granite saprolite
Lovills Creek			
E-E'	D508	0-2	Road fill
		2-5	Dark-gray micaceous clayey fine sand
		5-7½	Dark-gray carbonaceous pebbly coarse sand
		7½-13½	Light-yellow pebbly medium sand
		13½-14	Yellow biotite schist saprolite
	D507	0-4	Brown micaceous silt, grades to silty clay, alternate layers of gray and brown, at 3
		4-6	Pebble-cobble gravel
		6	Unweathered bedrock
	D506	0-6½	Light-brown micaceous sandy silt, sand fine, gravelly at base
		6½-8	Dull-green biotite schist saprolite, unweathered biotite schist at base

ble 1. Drilling data, Yadkin River drainage basin, Surry County, N.C.--

continued

ction	Hole	Depth (ft)	Description of sediment
arat River			
'-F'	D505	0-18½	Light-brown sandy silt, sand fine, grades to medium sand at 7, grades to sandy pebble-cobble gravel, sand medium, at 13
		18½-19	Green and yellow-brown biotite schist saprolite
	D504	0-4½	Reddish-brown clayey silt
		4½-8	Light-brown medium sand
		8-11	Brown-black sandy pebble gravel, grades to pebble-cobble gravel at 10
		11-14	Greenish-gray biotite schist saprolite
	D503	0-8½	Light-yellow clayey silt, grades to gray silty clay at 4½
		8½-9	Blue-gray micaceous clayey silt
		9-12	Dark-gray-brown carbonaceous clayey silt
		12-14½	Light-brown sandy pebble gravel
		14½-19	Green and brown saprolite

Table 1. Drilling data, Yadkin River drainage basin, Surry County, N.C.--continued

Section	Hole	Depth (ft)	Description of sediment
Yadkin River			
G-G'	D499	0-1	Dark-brown silt
		1-14½	Light-brown sandy silt, sand fine
		14½-20½	Micaceous silt, alternate layers of gray and light brown, grades to silty pebble gravel at 18
		20½-24	Brown biotite schist saprolite
	D498	0-10	Yellow-brown micaceous silt, grades to sandy silt, sand fine, at 7
		10	Layer of black pebbly sand
		10-20	Yellow limonite-stained coarse sand, grades to gravelly sand at 15, grades to pebble-cobble gravel at 18½
		20-24	Blue granite saprolite

Table 1.--Drilling data, Yadkin River drainage basin, Surry County, N.C.--continued

Section	Hole	Depth (ft)	Description of sediment
G-G' cont.	D497	0-1	Yellow-brown sandy clay, sand fine
		1-1½	Gray clayey medium-coarse sand
		1½-20	Micaceous silty clay, upper 7½ ft alternate layers of gray and brown, grades to gray, grades to dark-brown peaty clay at 10, grades to blue-gray micaceous sandy silt, sand fine, at 14, grades to blue-gray micaceous medium sand at 17
		20-23	Yellow coarse sand, gravelly at base
		23-24	Greenish-gray saprolite
H-H'	D502	0-6	Silty fine sand, upper ½ ft dark brown, grades to light yellow-brown
		6-8½	Light-brown micaceous clayey silt
		8½-23	Light-brown silty fine sand, grades to pebbly medium-coarse sand at 15, grades to pebble-cobble gravel at 18½
		23-24	Yellow and white granite saprolite
	D501	0-23½	Light-brown sandy silt, sand fine, grades to gravelly medium-fine sand at 16½, grades to sandy pebble-cobble gravel, sand fine, at 20
		23½-24	White granite saprolite

Table 1. Drilling data, Yadkin River drainage basin, Surry County, N.C.--continued

Section	Hole	Depth (ft)	Description of sediment
H-H' cont.	D500	0-9½	Light-brown sandy silt, sand fine
		9½	Layer of black manganese-stained pebbly sand
		9½-13½	Light-brown micaceous medium sand
		13½-20½	Yellow coarse sand, grades to pebble-cobble gravel at 16½
		20½-24	Green biotite schist saprolite

Table 2. Drilling data, Dan River drainage basin, Surry and Stokes Counties, N.C. [See pl. 1]

Line	Hole	Depth (ft)	Description of sediment. Terms are those defined in Overstreet and others, 1968, p. 52-53.
Creek			
I-I'	D510	0-5	Silty fine sand, upper 4 ft light brown, grades to gray
		5-7	Light-gray medium-coarse sand, grades to pebbly sand at 6
		7-9	Gray-brown biotite schist saprolite
	D509	0-5½	Light-brown clayey silt, grades to gray clayey medium sand at 4½
		5½-8½	Light-gray pebbly medium-coarse sand
		8½-9	Gray-white granite saprolite
J-J'	D512	0-3	Brown silty clay
		3-7	Gray carbonaceous clayey silt
		7-11	Gray clayey medium-coarse sand, grades to pebbly sand at 10
		11-14	Light-brown biotite schist saprolite
	D511	0-2½	Dark-brown clayey silt
		2½-9½	Silty clay, alternate layers of gray and yellow-brown, grades to gray sandy silt, sand fine, at 5, grades to light blue-gray silty medium sand at 7
		9½-13	Yellow-brown coarse sand, grades to pebble gravel at 12
		13-14	Gray saprolite

Sediments ranging from fine sand to gravel are dominant throughout the area. Clay forms 6 percent of the total sediment along tributaries to the Yadkin River and 14 percent of the total sediment near the head of Big Creek. This is a lower percentage of clay than the average for the area between the Savannah and Catawba Rivers. The relative amount of gravel and coarse sand is higher between the Yadkin and Dan Rivers than it is to the southwest between the Savannah and Catawba Rivers. Flood plains drilled along tributaries to the Yadkin River and Dan River contained 18 percent gravel. Average composition of alluvial sediments in the area between the Savannah and Catawba Rivers is contrasted with the average composition of sediments in the area between the Yadkin and Dan Rivers:

Comparison of alluvial sediments

Sediment	Savannah-Catawba Rivers (percent of total sediment)	Yadkin-Dan Rivers (percent of total sediment)
Clay	26	10
Sand and silt	64	72
Gravel	10	18

Heavy minerals

Plate 1 shows sample localities, lines of auger drill holes, and isograms of heavy minerals for the Yadkin River-Dan River district. Alluvium was sampled at 124 stations. Of the 144 samples collected, 121 were taken from riffle gravel in stream channels, 2 are from riffle sand, and 21 were taken from sediments exposed in stream banks.

Monazite is scarce in the area between the Yadkin and Dan Rivers (table 3). Only 21 of the riffle gravel samples contain more than a trace of monazite, and only 2 of these exceed a tenor of 1 pound of monazite per cubic yard. The maximum tenor attained is 1.8 pounds of monazite per cubic yard in sample 52-WE-589 on Faggs Creek in Stokes County, N.C.

The 1 percent monazite isogram encloses parts of northeastern Surry County, northwestern Stokes County, and southwestern Patrick County along a north-northeast-trending zone east of Mount Airy. Small, isolated, monazite-bearing areas are shown by the isograms on Stewarts Creek and the Fisher River southwest of Mount Airy, and by isograms west of Danbury. The highest monazite isogram attained is the 10 percent contour which forms two small closures on Big Creek.

West and southwest of the monazite zone is an area rich in staurolite which rises to a high of 50 percent midway between Mount Airy and the Yadkin River. Epidote, absent within the staurolite zone, is present to the northwest and southeast. The 1 percent epidote contour is parallel to the boundaries of the staurolite-rich zone. Isograms for both these minerals follow the regional structural trend toward the northeast.

Ilmenite isograms form an 80 percent plateau that trends to the northeast across central Surry County. A high rises to 100 percent between Stewarts Creek and the Little Fisher River west of Mount Airy. A depression below the 80-percent plateau leads northeastward from the Fisher River to the head of Big Creek along the staurolite-rich zone. On the west side of the 80 percent plateau, the ilmenite isograms decrease to 40 percent in a zone of magnetite highs.

Magnetite is common only in northwestern Surry County in the headwaters of Stewarts Creek and the Little Fisher River, and in the upper reaches of the Fisher and Mitchell Rivers. There the magnetite isograms increase from 1 to 70 percent where the ilmenite isograms fall away from their 80 percent plateau.

Rutile is sporadically distributed; most rutile-bearing areas are associated spatially with the margin of the 80 percent ilmenite plateau and the 1 percent threshold contour for magnetite. Thus rutile appears where ilmenite begins to decrease and magnetite begins to increase.

The relations of garnet are obscure. Although garnet is moderately abundant and widely distributed in the area, the garnet isograms do not follow the strong trends established by ilmenite, magnetite, staurolite, and epidote. The best defined northeasterly trend in garnet isograms is in a small area around Toms Creek and the Ararat River southeast of Mount Airy. Near Mount Airy the garnet isograms rise from 1 to 5 percent transverse to the regional structure. This transverse rise in garnet may be related to the introduction of the granite near Mount Airy.

The 1 percent zircon isogram encloses much of the area that is within the 1 percent monazite isogram. Zircon is more common southwest of the Ararat River than is monazite and attains its maximum of 10 percent on a small tributary to the Yadkin River between the Fisher and Ararat Rivers.

The few tourmaline-bearing areas discovered are closely associated spatially with the zircon- and monazite-bearing areas. This association may be genetic; all three minerals are probably derived from bodies of granite and pegmatite.

Sillimanite and kyanite are virtually absent from alluvial heavy minerals between the Yadkin and Dan Rivers.

Spectrographic analyses were made on five samples, one of which contained a trace of monazite (table 4). Thorium was detected only in the sample containing monazite. Niobium is present in all samples, regardless of the absence or presence of rutile. High percentages of ilmenite probably account for it. Mineralogical analyses of the five samples analyzed spectrographically are shown in table 5.

Table 4. Spectrographic analyses (in percent) of stream concentrates

/Analyses by C. S. Annel, U.S. Geological Survey/

Stream	Sample Number	XO.	X.	.X	.0X	.00X	.000X
			Streams between the Yadkin and Dan Rivers, N.C. and Va.				
Fisher River	52-WE-446	Fe Ti	Si Al	Ca Zr Mg Mn	Ce Cr Nd Nb Co	Pb La Y V Sr Sc Ba Cu	Yb
Stewarts Creek	52-WE-509	Fe Ti	Si Al	Ca Mg Mn Zr	Cr Nb Co	Pb V Sr Ba Cu Sc	Yb
Ararat River	52-WE-524	Fe Ti	Si Al	Ca Mg Mn Zr	Nb Co	Cr Pb V Sr Ba Cu Sc	Yb
Toms Creek	52-WE-536	Fe Ti	Al Si	Zr Ca Mg Mn	Ce Nd Th Gd La Cr Nb Y Co	Pb V Sr Ba Cu Yb Sc	--
Big Creek	52-WE-550	Fe	Ti Al Si	Mg Ca Mn Zr	Ce Nd Gd Co La Y Cr	Nb Pb V Cu Ba Sr Sc	Yb
			Streams in the drainage basin of the Oconee River, Ga.				
Barber Creek	52-PK-174	Fe Ti	Si	Ce Al Nd P La Zr Pr Y Th Mg Ca Sm Mn	Gd Nb Dy Cr Pb Co	Yb V Cu Sc Ba	--
McNutt Creek	**52-PK-198**	**Fe Ti**	**Si Al Ce**	Nd P Y **Zr Mn La** Th Mg Sm Pr Ca	Gd Dy Yb **Nb Cr Co** Sc	Pb V Sc Cu Ba Sr	--
Flat Creek	52-DC-790	Fe Ti	Si	Ce Al Mn Nd Ca P La Pr Th Sm Mg Y	Nb Gd Zr Pb Co Cr	Sn V Dy Yb Sc Cu Ba	--
Shoal Creek	52-DC-795	Fe Ti	Si	Al Ca Mn	Mg Ce Zr Nd Co Nb Cr V	La Ba Cu Sr Sc	--
Heads Creek	52-DC-804	Fe Ti	Si	Al Mn Ca Mg	Ce Zr V Nd Gd Co La Cr	Y Nb Pb Cu Ba Sr Sc	Yb
			Streams in the drainage basin of the Chattahoochee River, Ga.				
Yellowjacket Creek	52-DC-710	Fe Ti	Si Al	Zr Ca Mg Mn Ce	Th Y Nd Cr La Co Nb V	Cu Pb Yb Sc Ba Sr	--
Long Cane Creek	52-DC-730	Fe Ti	Si Al	Ca Mg Mn	Y Ce Co Cr Zr Nd V	La Cu Nb Yb Ba Sc Sr	--
Flat Shoals Creek	52-DC-777	Fe Ti	Si	Ce Zr Nd Th Al Ca Mn P Y La Pr Sm Mg	Gd Co Dy Nb Pb Cr	Yb Cu Sc V	--
Mountain Creek	52-DC-783	Al Ti Fe	Si	Ce Zr Mn Mg Nd Ca Th Y	La Sm Zn Cr Gd Co Sn Nb Pb	Dy Cu Yb V Sc Ba	Be

Table 5.--Mineralogical analyses of concentrates from streams between the Yadkin and Dan Rivers, N.C.--Va. [Tr, Trace; --, not found]

Mineral	Percent of concentrate				
	52-WE-446 Fisher River	52-WE-509 Stewarts Creek	52-WE-524 Ararat River	52-WE-536 Toms Creek	52-WE-551 Big Creek
Monazite	--	--	--	tr	--
Ilmenite	76	80	78	54	34
Rutile	--	--	--	tr	tr
Garnet	6	6	5	3	5
Zircon	1	4	--	2	tr
Sillimanite	--	--	--	tr	tr
Magnetite	3	1	1	24	41
Tourmaline	--	--	--	--	1
Staurolite	tr	--	--	4	6
Amphibole	--	--	--	tr	2
Quartz	14	9	16	9	9
Epidote	tr	--	tr	3	1
Hematite	--	--	--	1	--
Kyanite	--	--	--	tr	1

Appraisal

No flood plain between the Yadkin River and Dan River is a monazite placer. Two factors combine to preclude the possibility of a placer: (1) scarcity of monazite, and (2) small flood plains. Most of the streams do not contain monazite. In streams where monazite is found, riffle gravel samples (normally the richest of the sediments) contain a maximum of 1.8 pounds of monazite to the cubic yard, and the finer grained sediments contain but a trace. Most of the flood plains are small and discontinuous, and the larger flood plains are outside the areas of monazite-bearing bedrock.

Ilmenite and staurolite are common minerals in many streams between the Yadkin and Dan Rivers, but the abundance of both decreases toward the larger flood plains in the upper parts of the streams west of Mount Airy. The two minerals do not occur as large-volume placers on the Fisher and Ararat Rivers. Their distribution in the floodplain sediments along the Yadkin River is not known, but it is inferred that between the mouth of the Fisher River and the Surry County-Stokes County line they should be among the most abundant of the heavy minerals in the Yadkin River.

Deposits in the drainage basin of the Oconee River, Georgia

The North Oconee, Middle Oconee, and Mulberry Rivers rise in the Piedmont province in Hall County, Ga., and flow southeastward into Jackson County, Ga. Twenty miles from its head the Mulberry River, which forms the Barrow County-Jackson County line along the lower part of its course, joins the Middle Oconee River. The Middle Oconee River flows southeast for 25 miles to its junction with the Mulberry River and continues for 18 miles to its junction with the North Oconee River.

From this junction the Oconee River flows south for 170 miles to join the Ocmulgee River. The Apalachee River rises in the Piedmont province in Gwinnett County, Ga., and flows southeast for 52 miles to the Oconee River.

The area studied (pl. 2) includes 310 square miles of the Oconee River drainage basin in Oconee County, Barrow County, northwestern Clarke County, southeastern Jackson County, and western Oglethorpe County. The streams sampled include: Marburg Creek, tributary to the Apalachee River in Barrow County; Sandy, Falling, and Barrow Creeks, tributary to the Oconee River in Oglethorpe County; Rose Creek, an unnamed stream, Wildcat Creek, and Porters Creek, tributary to the Oconee River in Oconee County; Butler, Barber and McNutt Creeks, tributary to the Middle Oconee River in Oconee County; two unnamed streams and Bear Creek, tributary to the Middle Oconee River in Clarke County; Beech Creek, tributary to the Middle Oconee River in Barrow County; and Barbers, Cedar, and Hawk Creeks, tributary to the Mulberry River in Barrow County. A total of 96 samples was taken at 85 localities on these streams, and 26 auger holes were drilled on the flood plains of the streams at ten localities.

Most of the population is centered around the small towns. Winder, the county seat of Barrow County, is the largest of these and has a population of 5,500. Athens, just east of the area in Clarke County, has a population of 31,000. The Seaboard Coast Line Railroad traverses Barrow County and maintains sidings at several of the communities, and the Central of Georgia Railway, which crosses Oconee County, has sidings at Watkinsville. Both these railroads and the Southern Railway serve Athens.

The rivers are entrenched and generally flow through narrow gorges, but the larger tributaries, particularly Barber Creek, flow on the upland that forms the divide between the rivers. This upland is a broad, gently rolling surface that shows little dissection, and on which small sinklike depressions and bogs are common. Unweathered rock is rare on this upland; the most resistant rock observed was a lens of weathered quartzite that forms a ridge at the head of Little Bear Creek.

Granite underlies most of Clarke County and extends to the south into Oconee County and Oglethorpe County. It has intruded biotite schist and sillimanite schist. Along the margins of the granite is a migmatitic complex of schist, gneiss, and granite, blocks and septa of schist are included in the granite. Most of the area studied between southern Barrow County and northwestern Oglethorpe County is underlain by the migmatitic complex.

In central Barrow County the bedrock is a massive to gneissic biotite granite which ranges in composition from a massive granite containing disseminated biotite to a biotite-rich augen gneiss. The massive phase is most common in the headwaters of Marburg Creek and can be readily separated from the augen gneiss, although, for the purposes of this appraisal, the separation is unnecessary. Hornblende gneiss was seen along Barber Creek. In Oglethorpe County, massive biotite granite is shown on the geologic map of Georgia as being of the Stone Mountain type.

Foliation generally trends north to northeast and dips to the south. In the augen gneiss the strike of foliation is consistent and ranges from N. 15°-50° E. The rocks dip from 5°-40° S. In the area underlain by the schist and migmatitic complex, however, the strike is erratic and ranges from N. 40° W. through north to N. 80° E. The dips are equally erratic, ranging from 35° N. through vertical to 15° S.

The stream pattern in Oconee County has no relation to the major structures. It is dominated by paralllel, southeast-flowing, consequent streams. North of Bear Creek the tributaries to the Mulberry River generally follow the strike of the augen gneiss.

Alluvium

The Middle Oconee River enters the monazite belt at its confluence with the Mulberry River. There are large flood plains along the river in this part of the belt, but downstream from the mouth of Bear Creek the river drops into the gorge that it follows for the remainder of its course across the belt. The largest flood plain in the area is along the Middle Oconee River, extending from the mouth of Bear Creek to the upper end of the gorge. The flood plain is 13,000 feet long, averages 1,900 feet wide, and contains an estimated 18 million cubic yards of alluvium.

Bear Creek is the only one of the monazite-rich streams that has a large flood plain at its mouth. This flood plain is continuous with the flood plain described above, is 12,000 feet long, averages 700 feet wide, and contains an estimated 5 million cubic yards of alluvium. Bedrock shoals separate this flood plain from the remainder of the flood plains in the Bear Creek drainage basin, but above the shoals the flood plains on both Bear and Little Bear Creeks are continuous nearly to the heads of the streams.

Barber Creek and McNutt Creek join 4,000 feet upstream from the Middle Oconee River. At their junction, both streams are flowing on bedrock, and bedrock shoals separate the pocketty flood plains on both streams for 4 miles upstream on McNutt Creek and for 10 miles upstream on Barber Creek. Above the shoals flood plains are continuous nearly to the heads of the streams. At their heads the streams approach the level of the divides, the valleys are shallow, and the flood plains appear to merge with the upland surface.

On McNutt Creek the flood plains attain a maximum width of 1,300 feet just upstream from the shoals. Upstream from this flood plain the stream passes through a narrow gorge across a cutoff spur, but the flood plain is continuous around the nose of the spur in the old channel. One pronounced constriction of the flood plains on McNutt Creek occurs where sample 52-PK-206 was taken. This is the only natural constriction that would interrupt mining above the shoals.

On Barber Creek the flood plain is more continuous and wider above the shoals than on the other streams. Aerial photographs were not obtained for field work on this stream above sample 52-PK-191, but the flood plain between samples 52-PK-191 and 52-PK-187 is 27,800 feet long, averages 970 feet wide, and contains an estimated 12 million cubic yards of alluvium. This flood plain continues upstream, but it is broken at the lower end by bedrock shoals.

Like Barber Creek, Butler Creek is entrenched along its lower reaches. The only flood plains along this stream are near its head. In this area the stream and its flood plains are small, and the largest flood plain is 600 feet wide northeast of Watkinsville. The flood plains on Porters and Wildcat Creeks are similar in size and distribution to those on Butler Creek.

The flood plains on Rose Creek are similar to those on Barber Creek. No aerial photographs were obtained for field work on the lower part of this stream, so only the general features of the distribution of alluvium can be given. The constriction on the lower parts of the streams farther north is not present at the mouth of Rose Creek where a broad flood plain extends from the place where sample 52-PK-270 was taken to the river. On this stream the bedrock shoals are below sample 52-PK-267. A narrow flood plain extends upstream from sample 52-PK-267, and small flood plains are in the headwaters of the east-flowing tributaries to Rose Creek.

The average thickness of alluvium recorded from auger drilling is 12.3 feet (table 6). The deepest sediments are in the flood

Table 6.--NEAR HERE

plain of the Oconee River, D538 at J-J', and in the flood plains above the shoals on McNutt Creek, D532, D533, and D534 at I-I'. At the remainder of the holes, drilled on the upper part of McNutt Creek and Barber Creek, the sediment is less than 16.5 feet deep.

The sequence of the sediments is similar to that found in Anderson County, S.C. Clayey sediments are usually on or near the surface of the flood plain, and they grade downward to sand. A thin layer of gravel is at the base of the section in some places. The average proportions of the sediments disclosed by drilling are: 3 percent gravel, 41 percent sand, 24 percent silt, and 32 percent clay. The low proportion of gravel in the area is unfavorable for placers in the large, upland flood plains, and even if a mining operation could recover heavy minerals from both gravel and sand, the stripping ratio would still be greater than 1 to 1.

Table 6.--Drilling data, Oconee River drainage basin, Oconee County, Ga. [See pl. 2]

Section	Hole	Depth (ft)	Description of sediment. Terms are those defined in Overstreet and others, 1968, p. 52-53
Barber Creek			
A-A'	D513	0-½	Reddish-brown clayey silt
		½-8½	Mottled gray and red sandy clay, sand medium-coarse, grades to mottled dull-green and blue-gray sandy clay, sand fine, at 4, grades to clayey medium sand at 5, grades to dull-green clayey medium-coarse sand at 5½, grades to pebbly coarse sand at 7½
		8½-9	Red sandy clay, sand coarse
		9-12	Pale-yellow pebbly coarse sand, grades to sandy pebble gravel at 11
		12-14	Brown biotite schist saprolite
	D514	0-16	Mottled gray and light-brown sandy clay, sand medium, grades to gray sandy clay, sand fine, at 6½, grades to micaceous clayey coarse sand at 10½, grades to pebble-cobble gravel at 15
		16-19	Brown biotite schist saprolite
	D515	0-12½	Dull-greenish-brown sandy clay, sand coarse, grades to gravel at 10½
		12½-14	Greenish-gray biotite gneiss saprolite

Table 6.--Drilling data, Oconee River drainage basin, Oconee County, Ga.--continued

Section	Hole	Depth (ft)	Description of sediment
B-B'	D517	0-15½	Sandy silty clay, sand medium, upper 2 ft dark-red-brown grades to mottled yellow-brown and gray, grades to dull greenish gray at 6, grades to yellow-brown clayey medium-fine sand at 11½, grades to pebbly coarse sand at 13, pebble gravel at base
		15½-19	Brown biotite gneiss saprolite
	D516	0-3	Red sandy clay, sand medium, grades to dull gray clayey coarse sand at 1½
		3-13½	Gray-black micaceous carbonaceous clayey silt, grades to gray-white coarse sand at 8½, grades to orange sandy pebble gravel, sand coarse, at 13
		13½-14	Yellowish-white granite saprolite
C-C'	D518	0-½	Reddish-brown medium-fine sand
		½-4½	Dark-brown clayey silt
		4½-10½	Dark-blue-gray carbonaceous silty clay, grades to micaceous carbonaceous sandy clay, sand fine, at 8, grades to pebbly coarse sand at 10
		10½-14	Brown biotite gneiss saprolite
	D519	0-5	Blue-gray micaceous carbonaceous silty clay
		5-9½	Gray-white medium-coarse sand, grades to pebble gravel at 9
		9½-14	Brown biotite gneiss saprolite

Table 6.--Drilling data, Oconee River drainage basin, Oconee County, Ga.--continued

Section	Hole	Depth (ft)	Description of sediment
C-C' cont.	D520	0-6½	Red-brown clay, grades to gray-black carbonaceous clay at ½
		6½-7½	Yellow-brown pebbly coarse sand
		7½-9	Brown biotite schist saprolite
D-D'	D521	0-2½	Light-brown silt
		2½-11½	Yellow-brown sandy silt, sand coarse, grades to gray clayey coarse sand at 5, grades to gray-white pebbly sand at 7½
		11½-14	Blue-white granite saprolite
	D522	0-5	Light-brown sandy silt, sand fine
		5-13½	Gray-white clayey medium-fine sand, grades to yellow-brown gravelly medium-coarse sand at 9½
		13½-14	Brown biotite schist saprolite
E-E'	D525	0-½	Red clayey silt
		½-6½	Yellow-brown clayey medium-coarse sand
		6½-13	Biotite gneiss saprolite
		13	Unweathered biotite gneiss
	D524	0-½	Dull-red sandy silt, sand fine
		½-5½	Light-gray-brown sandy clay, sand medium-fine
		5½-7	Pale-yellow-gray pebbly clay
		7-9	Brown biotite schist saprolite
	D523	0-5	Dull-red sandy silt, sand fine
		5-12	Dark blue-gray carbonaceous clayey silt, grades to gray carbonaceous clayey coarse

Table 6.--Drilling data, Oconee River drainage basin, Oconee County, Ga.--continued

Section	Hole	Depth (ft)	Description of sediment
E-E' cont.		5-12	sand at 6½, grades to sandy pebble gravel at 11½
		12-14	Green biotite schist saprolite
F-F'	D528	0-3	Orange silt
		3-8½	Gray clayey medium sand, grades to dark-gray carbonaceous clay at 6½
		8½-9	Yellow-brown pebbly coarse sand
		9-14	Biotite granite gneiss saprolite, upper 1 ft green, grades to yellow-brown
	D527	0-1	Dark-brown sandy silt, sand medium, grades to coarse sand at base
		1-7½	Gray clayey coarse sand, pebbly at base
		7½-9	Gray-brown biotite gneiss saprolite
	D526	0-½	Dull-red silt
		½-7½	Gray sandy clay, sand medium-coarse, grades to pebbly coarse sand at 5½, grades to pebble gravel at 7
		7½-9	Green biotite gneiss saprolite
G-G'	D529	0-6½	Red sandy silt, sand fine
		6½-15½	Gray-brown micaceous silty clay, grades to dark-gray carbonaceous sandy clay, sand fine, at 7½, grades to gray carbonaceous clayey medium-coarse sand at 9
		15½-19	Green saprolite

Table 6.--Drilling data, Oconee River drainage basin, Oconee County, Ga.--continued

Section	Hole	Depth (ft)	Description of sediment
G-G' cont.	D530	0-15	Reddish-brown micaceous silty medium-coarse sand, grades to gray clayey coarse sand at 5, lens of carbonaceous clay 6-6½, layer of gray peaty clay 9-10½, grades to yellow-brown pebbly sand at 13, grades to pebble gravel at 14
		15-19	Yellow biotite schist saprolite
	D531	0-1	Red silty medium-coarse sand
		1-4½	Micaceous carbonaceous silty clay, upper 1½ ft gray-brown grades to dark gray
		4½-10	Light-gray clayey medium-coarse sand, grades to micaceous sandy silt, sand medium-fine, at 8, pebbly at base
		10-14	Bright blue-gray biotite gneiss saprolite
McNutt Creek			
H-H'	D537	0-2	Red coarse sand
		2	Lens of gray carbonaceous clayey silt
		2-9	Gray clayey coarse sand, pebbly at base
		9	Yellow biotite schist saprolite
	D536	0-6	Silty clay, upper 4½ ft mottled gray and yellow-brown, grades to blue-gray
		6-9	Gray-white coarse sand
		9	Yellow biotite schist saprolite
	D535	0-4½	Yellow sandy silt, sand fine

Table 6.--Drilling data, Oconee River drainage basin, Oconee County, Ga.--continued

Section	Hole	Depth (ft)	Description of sediment
H-H' cont.		4½-9	Greenish-gray biotite gneiss saprolite
I-I'	D532	0-½	Red medium-coarse sand
		½-12	Brown micaceous silty clay, grades to gray-brown micaceous carbonaceous silty clay at 2, fresh wood at 7
		12-16½	Yellow-gray pebbly coarse sand
		16½-19	Brown biotite schist saprolite
	D533	0-5	Reddish-brown sandy silt, sand fine, grades to medium-coarse sand at 2½
		5-12½	Mottled brown and blue-gray micaceous sandy clay, sand fine, grades to blue-gray micaceous silty fine sand at 11
		12½-18½	Pale yellow-brown medium-coarse sand, grades to pebble gravel at 17½
		18½-19	Yellowish-white granite gneiss saprolite
	D534	0-4	Reddish-brown micaceous sandy silt, sand fine
		4-8½	Gray-brown carbonaceous silty clay, grades to dark-gray micaceous carbonaceous clayey silt at 5, grades to blue-gray carbonaceous clayey medium sand at 7½
		8½-14½	Gray micaceous carbonaceous clayey silt, grades to gray-white coarse sand at 11
		14½-16	Dark-gray micaceous carbonaceous clayey medium-fine sand

Table 6.--Drilling data, Oconee River drainage basin, Oconee County, Ga.--continued

Section	Hole	Depth (ft)	Description of sediment
I-I' cont.		16-20½	Gray-white pebbly coarse sand, grades to pebble gravel at 19½
		20½-24	Greenish-brown biotite schist saprolite
Oconee River			
J-J'	D53S	0-23½	Reddish-brown silty medium-fine sand, grades to brown medium-coarse sand at 5½, grades to light-brown micaceous sandy silt, sand fine, at 9
		23½-29½	Micaceous clayey silt, upper 2½ ft. light brown, grades to mottled gray and brown
		29½-30	Gravel

Heavy minerals

Monazite is in 93 percent of the riffle gravel samples taken in the drainage basin of the Oconee River (table 7). In 64 percent of the

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Table 7.--NEAR HERE

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riffle gravel samples there is more than 1 pound of monazite per cubic yard, and in 3 of the riffle gravel samples there is more than 5 pounds of monazite per cubic yard. The average tenor of the 55 riffle gravel samples is 2.1 pounds of monazite per cubic yard.

Riffle sand samples present a similar pattern at a lower tenor. Sixty-nine percent contain monazite: 10 percent contain more than 1 pound per cubic yard, 2 samples contain more than 5 pounds per cubic yard, and the average tenor of the 30 samples is 0.7 pound per cubic yard. Too few samples were taken from flood-plain sediments to compute an accurate average for the area, but all 11 of these samples contain monazite. The bank samples are distributed among the sediments as follows: 1 from clay, 3 from sand, 3 from gravel, and 4 from silt. One of the bank-gravel samples, 52-PK-227, contains 6.9 pounds of monazite per cubic yard; it is the only bank sample to exceed 1 pound per cubic yard.

The highest tenors in monazite cluster in three areas underlain by the migmatitic complex: (1) associated with the isogram high at the heads of McNutt and Bear Creeks, (2) associated with the isogram high on lower Barber Creek and at the head of Butler Creek, and (3) associated with the isogram high on central Rose Creek and extending north across the head of Wildcat Creek and lower Porters Creek. The high-tenor areas appear to converge toward the monazite-bearing granite at Athens, though the southernmost high may continue across northwestern Oglethorpe County to connect with the southern extension of the highs along the Abbeville County-Anderson County line in South Carolina (Overstreet and others, 1968, pl. 3).

The zone of lowest tenor in the areas underlain by the migmatitic complex includes the largest flood plains, which are on Barber Creek and the Middle Oconee River. A few field observations of panned concentrates from bedrock in the area indicated that monazite is confined to the granite and its associated pegmatite exposed in Clarke County. No monazite was found in biotite schist or the granites in Oglethorpe County and central Barrow County. The migmatitic complex is a competent rock that resists weathering, but the biotite and sillimanite schists, when not extensively intruded by the granite, weather rapidly. Few rocks crop out in the area of low tenors and large flood plains, but it is inferred that this area is underlain by the incompetent schists.

Potential byproducts of placer mining in the area are ilmenite, rutile, zircon, and garnet. Ilmenite is in all the samples and is most abundant on Bear Creek. The highest tenor is 78.7 pounds of ilmenite per cubic yard of riffle gravel in 52-PK-192, and the average tenor of riffle samples is 15.6 pounds per cubic yard of riffle gravel and 7.4 pounds per cubic yard of riffle sand. The 12 riffle gravel samples on Bear Creek average 26.8 pounds of ilmenite per cubic yard.

Rutile is most abundant on Butler Creek, the upper part of Barber Creek, and Bear Creek. It is present in 38 percent of the riffle gravel samples and in 33 percent of the riffle sand samples.

The maximum tenor in rutile is 1.7 pounds per cubic yard in sample 52-PK-218, and the average tenor of samples containing rutile is 0.5 pound per cubic yard of riffle gravel and 0.3 pound per cubic yard of riffle sand.

Zircon is most abundant in the samples from central Barrow County where it is associated with granite and augen gneiss. Field examination of panned concentrates from saprolite of these two rocks showed that the heavy-mineral suite from the granite was composed almost entirely of zircon, and that this suite was modified only by the addition of magnetite in the augen gneiss.

Zircon is in 73 percent of the riffle gravel samples and 77 percent of the riffle sand samples. The average tenor of riffle samples containing zircon is 0.7 pound per cubic yard of gravel and 0.4 pound per cubic yard of sand. The maximum tenor is 3.6 pounds per cubic yard in sample 52-PK-250.

Garnet is uniformly distributed through the area underlain by schists and gneisses. The maximum tenor is 3.7 pounds of garnet per cubic yard in sample 52-PK-192, and the average tenors of all riffle samples are 0.6 pound per cubic yard of gravel and 0.2 pound per cubic yard of sand.

With the exception of 52-PK-261 which contains 1.3 pounds of sillimanite per cubic yard, none of the samples contains more than 0.8 pound per cubic yard of either kyanite or sillimanite. Kyanite is in only two of the samples. Sillimanite is in 27 percent of the riffle gravel samples and 50 percent of the riffle sand samples, most of which are in the southern half of Oconee County. The average tenors of riffle samples containing sillimanite are only 0.3 pound per cubic yard of gravel and 0.2 pound per cubic yard of sand.

The area may be subdivided on a basis of heavy-mineral suites into three major mineralogic provinces: (1) a high-magnetite, zircon-bearing province associated with the granite and gneiss in Barrow County; (2) the central monazite-bearing province in Oconee County; and (3) a high-magnetite province associated with the granite in Oglethorpe County. Small amounts of epidote are associated with the two magnetite suites, and in both of these suites there is scant monazite.

The greatest variety of minerals is in the central province which is associated with the high-rank metamorphic rocks, the migmatitic complex, and the granite in Clarke County. There are three heavy-mineral suites in this province, each associated with one of the high-monazite zones: (1) a sillimanite-monazite suite on Rose, Wildcat, and Porters Creek; (2) a rutile-zircon-monazite suite on Butler Creek and lower Barber Creek; and (3) a zircon-monazite suite on central Barber Creek and Bear Creek. The differences in these three suites probably result from original differences in the character of the gneiss.

Mineralogical analyses of three concentrates from Oconee County are given in table 8; table 4 shows spectrographic analyses of these concentrates.

Appraisal

In the narrow, cross-strike band that was sampled, the tenors are favorable for placers, and the two large flood plains on the Middle Oconee River and Barber Creek would be worthy of further examination

Table 8.--Mineralogical analyses of three concentrates from streams in the drainage basin of the Oconee River, Ga.

[tr, trace; --, not found]

Mineral	Percent of concentrate		
	52-PK-174 Barber Creek	52-PK-198 McNutt Creek	52-PK-269 Rose Creek
Monazite	8	13	2
Ilmenite	63	48	48
Rutile	7	1	tr
Garnet	2	2	2
Zircon	4	3	1
Sillimanite	tr	tr	1
Magnetite	2	4	20
Amphibole	--	tr	--
Epidote	tr	--	tr
Quartz	14	26	22
Hematite	--	3	4

should there be further interest in southeastern monazite. It seems, however, that the largest flood plains are formed in areas underlain by easily weathered rocks, such as biotite schist that is a relatively poor source for monazite. In addition, the proportion of gravel in the large flood plains is small and the stripping ratio is high.

No limits were established along the strike of the high-tenor area. The general trends of the monazite highs in the area sampled are converging toward the northeast, suggesting that the highest consistent tenors surround the granite exposed at Athens and that the monazite content of the streams would decrease to the southwest.

The high tenors of three of the riffle gravel samples and two of the riffle sand samples would be suitable for small-scale mines if a favorable market were available.

Although this is a favorable area for further exploration, both reconnaissance and detailed, it is not comparable in area, tenor, or volume of gravel to the core of the monazite belt in North Carolina and South Carolina. Thus, further exploration should not be attempted in the Oconee River drainage basin until all possibilities have been exhausted in the North Carolina-South Carolina area or until mining has been established in the Carolinas.

Deposits in the drainage basin of the Flint River, Georgia

The Flint River rises in the Piedmont in Fulton County, Ga., near East Point on the southern outskirts of Atlanta. From East Point the river flows 22 miles southward to the northwestern corner of Spalding County, and, maintaining its southerly course, forms most of the west boundary of Spalding County and the west boundary of Pike County (pl. 3). The Flint River swings southeastward toward the Ocmulgee River and enters Coastal Plain sediments 90 miles from its source and 35 miles from the southwest corner of Pike County.

Reconnaissance was restricted to 210 square miles in western Spalding County and Pike County between Griffin, Zebulon, and the Flint River. Although the largest town in the area, Griffin, has a population of 22,000 the rural areas are sparsely settled. Few roads in the two counties have been paved, but there is a good net of unpaved roads. Both the Central of Georgia and the Southern Railway pass through Griffin, and the Southern Railway serves Zebulon.

The area between Griffin, Zebulon, and the Flint River is underlain by biotite granite intrusive into biotite gneiss and biotite schist (Stose and Smith, 1939). Poorly developed foliation in the granite trends N. 20° E. to N. 10° W. and dips gently eastward. Observations at a few places show that the rocks strike N. 20-40° E. and have a gentle southeasterly dip. No contacts between the granite and the gneiss and schist were seen, and structural relations in the area are not known.

About 5 miles south of Elkins Creek the Flint River flows across quartzite, which, because of its resistance to erosion, has produced a graded reach. Many of the tributaries to the Flint River upstream from the quartzite have low gradients, flow sluggishly on fine-grained sediment, and are swampy to their sources. Watersheds lie along broad interstream areas in the gently rolling hills typical of the southeastern Piedmont 30 to 40 miles from the Coastal Plain.

North of Elkins Creek the tributaries to the Flint River that were sampled include five short, unnamed streams, Birch Creek, Flat Creek, and Wildcat Creek. Wildcat Creek has two eastern branches: the one that heads near Griffin is called Shoal Creek; the more northerly branch is named Heads Creek. South of Griffin near the line between Spalding County and Pike County one sample was taken on Honey Bee Creek, a tributary to Potato Creek.

Alluvium

Flood plains commonly are 100 to 1,100 feet wide, 7 to 20 feet deep, a few hundred yards to 2 miles long, and are discontinuous. Irregularities on the saprolitic bedrock floors of the valleys result in 3 to 8 feet of relief which is generally a slip-off slope rather than a narrow channel carved in an otherwise flat floor.

Eighteen auger drill holes were sunk along 10 lines across the flood plains on Heads, Shoal, Wildcat, and Flat Creeks, and the Flint River (table 9, pl. 3). The average depth of alluvium is 13 feet, which is maintained well up toward the sources of Heads and Shoal Creeks (sections A-A', B-B', and D-D') and is attained within the upper one-third of the Flat Creek drainage (sections F-F' and H-H'). From the valley floors upward, the flood-plain sediments grade from thin sheets of gravel or pebbly sand through coarse sand to clayey fine sand and clay. Generally the uppermost sediments are brown, gray, or black sandy or silty clay; rarely the sediments at the surface of the flood plain are red or orange clay (D480 and D484), and at a few places the upper sediment is reddish-brown silt or sand (D586, D589, D590, and D591).

Table 9.--Drilling data, Flint River drainage basin, Spalding County, Ga. [See pl. 3]

Section	Hole	Depth (ft)	Description of sediment. Terms are those defined in Overstreet and others, 1968, p. 52-53.
Wild Cat Creek			
A-A'	D477	0-3 1/2	Red-brown micaceous silty clay, grades to brown gravelly sand at 2
		3 1/2-5	Gray micaceous carbonaceous clay
		5-14 1/2	Mottled green and gray sandy clay, sand fine, grades to gray sandy clay, sand medium-fine at 7, grades to yellowish-gray clayey medium sand at 10, grades to light-brown clayey coarse sand at 11 1/2, grades to sandy pebble gravel at 13 1/2
		14 1/2-19	Brown biotite schist saprolite
	D478	0-1	Road fill
		1-4 1/2	Gray-black carbonaceous silty clay, upper 1 ft peaty
		4 1/2-17 1/2	Blue-black clayey medium-coarse sand, grades to gray-white coarse sand at 8, layer of blue-gray micaceous clayey silt 13 1/2-14, grades to pebbly sand at 16 1/2
		17 1/2-19	Greenish-gray biotite granite gneiss saprolite

Table 9.--Drilling data, Flint River drainage basin, Spalding County, Ga. [See pl.3], continued

Section	Hole	Depth (ft)	Description of sediment.
B-B'	D479	0-1	Red-brown sandy clay, sand medium
		1-5	Gray carbonaceous sandy clay, sand coarse, grades to carbonaceous clay at 2
		5-11 1/2	Gray carbonaceous clayey coarse sand, layer of peaty sand 7-8, gravelly at base
		11 1/2-14	Blue-gray biotite schist saprolite
	D480	0-1 1/2	Orange micaceous silty clay
		1 1/2-5	Gray-brown carbonaceous clay
		5-8 1/2	Blue-gray sandy clay, sand fine, grades to purple clayey medium sand at 7 1/2
		8 1/2-9	Gray-white clayey coarse sand
		9-14	Gray micaceous carbonaceous silty clay
		14	Sheet of saprolite on brown unweathered biotite gneiss
C-C'	D481	0-7	Road fill
		7-10	Mottled green and gray clay
		10-14	Light-brown medium-coarse sand
		14-19	Brown biotite schist saprolite

Table 9.--Drilling data, Flint River drainage basin, Spalding County, Ga.[See pl. 3],continued

Section	Hole	Depth (ft)	Description of sediment
D-D'	D484	0-1/2	Red clay
		1/2-3	Brown clayey silt
		3-11 1/2	Blue-gray clayey fine sand, grades to coarse sand at 7, gravelly at base
		11 1/2-14	Blue-gray to brown biotite schist saprolite
	D483	0-3	Dark-brown sandy clay, sand medium
		3-3 1/2	Orange-brown clayey medium-coarse sand
		3 1/2-17	Gray carbonaceous clay, grades to blue-gray clayey medium sand at 5, grades to gray-white coarse sand at 8, grades to granule sand at 11, grades to pebble-cobble gravel at 16 1/2
		17-19	Blue-gray biotite granite gneiss saprolite
E-E'	D475	0-1/2	Dark-brown clay
		1/2-9 1/2	Clayey coarse sand, upper 4 ft white, grades to brown, grades to pebble-cobble gravel at 9
		9 1/2-12	Greenish-gray biotite schist saprolite
	D476	0-1	Gray carbonaceous sandy clay, sand medium
		1-13	White clayey coarse sand, grades to yellowish-white granule sand at 10
		13-14	Brown biotite schist saprolite

Table 9.--Drilling data, Flint River drainage basin, Spalding County, Ga. [See pl. 3], continued

Section	Hole	Depth (ft)	Description of sediment
E-E'	D474	0-1/2	Road fill
		1/2-13	Mottled gray and brown silty clay, grades to blue-gray clay at 4, grades to clayey medium sand at 5, grades to coarse sand at 7
		13-17	Blue-gray micaceous silty fine sand
		17-17 1/2	Brown biotite schist saprolite, unweathered biotite schist at base
	D473	0-1	Dark-gray carbonaceous silty clay
		1-16	Mottled gray and yellow-brown silty clay, grades to gray clayey fine sand at 5, grades to yellow-brown medium sand at 6 1/2, grades to brown coarse sand at 12, grades to gravelly sand at 14
		16-19	Brown biotite schist saprolite
Flat Creek			
F-F'	D586	0-12	Reddish-brown micaceous clayey silt, grades to micaceous sandy silt, sand medium, at 1 1/2, grades to gray carbonaceous medium-coarse sand at 4, grades to gray carbonaceous clayey pebbly coarse sand at 6
		12-12 1/2	Blue-gray granite saprolite, unweathered granite at base

Table 9.--Drilling data, Flint River drainage basin, Spalding County, Ga. [See pl. 3], continued

Section	Hole	Depth (ft)	Description of sediment
G-G'	D587	0-7	Sandy clay, sand medium, upper 2 ft red-brown, grades to greenish gray
		7-9	Brown biotite schist saprolite
	D588	0-3	Sandy clay, sand medium-coarse, upper 1 1/2 ft red, grades to black
		3-7 1/2	Gray carbonaceous sandy clay, sand medium, pebbly at base
		7 1/2-9	Blue-gray biotite granite gneiss saprolite
H-H'	D589	0-1/2	Reddish-brown medium-coarse sand
		1/2-4	Red-brown micaceous silty clay, grades to gray-brown carbonaceous silty clay at 1 1/2
		4-8	Gray carbonaceous sandy clay, sand medium
		8-19 1/2	Gray-white clayey medium-coarse sand, grades to pebble-cobble gravel at 18
		19 1/2-24	Gray-brown to brown biotite granite gneiss and biotite schist saprolite
I-I'	D591	0-1	Dark-brown silty medium-fine sand
		1-16 1/2	Yellow sandy clay, sand medium-fine, grades to white clayey medium sand at 5, grades to granule sand at 7 1/2, gravelly at base
		16 1/2-19	Brown biotite schist saprolite

Table 9.--Drilling data, Flint River drainage basin, Spalding County, Ga.[See pl. 3], continued

Section	Hole	Depth (ft)	Description of sediment
I-I'	D590	0-1	Dark-brown medium sand
		1-5	Yellow sandy clay, sand medium
		5-9	Mottled gray and yellow-brown micaceous silty clay
		9-13	Yellowish-white medium-coarse sand
		13-14	Gray-white granite saprolite
J-J'	D472	0-1 1/2	Dark-brown silty clay
		1 1/2-9 1/2	Yellow-gray sandy clay, sand medium-coarse, grades to gray sandy clay, sand medium-fine, at 6
		9 1/2-18	White medium-coarse sand
		18-19	Gray biotite granite gneiss saprolite

Table 10.—Tenors of sediments in the drainage basin of the Flint River, Ga.

[Tenors computed from mineralogical analyses by H. B. Groom, Jr., R. P. Marquiss, C. J. Spengler, and Jerome Stone, U.S. Geological Survey; tr, trace; --, not found]

Stream	Sample number	Sediment	Pounds per cubic yard					
			Monazite	Ilmenite	Rutile	Zircon	Garnet	Sillimanite
Honey Bee Creek	52-DC-813	Riffle sand	1.3	4.9	--	0.8	0.6	0.09
Elkins Creek	52-DC-812	Do.	.01	.2	tr	tr	.01	.01
	52-DC-811	Terrace gravel	--	5.5	--	--	--	--
Unnamed tributary	52-DC-810	Riffle gravel	1.6	3.2	--	--	--	--
Unnamed tributary	52-DC-809	Riffle sand	.6	8.1	--	.2	--	--
Unnamed tributary	52-DC-808	Riffle gravel	1.4	1.2	--	.08	.9	--
Birch Creek	52-DC-807	Do.	.06	1.9	--	--	--	--
Unnamed tributary	52-DC-805	Riffle sand	.4	7.8	0.3	--	--	--
	52-DC-806	Riffle gravel	3.6	20.4	1.0	--	--	--
Flat Creek	52-DC-792	Do.	1.0	6.4	.2	.1	.2	--
	52-DC-793	Do.	5.4	64.4	1.5	--	--	--
	52-DC-794	Do.	6.1	32.8	.9	--	--	--
	52-DC-791	Riffle sand	3.1	9.2	.3	--	--	--
	52-DC-790	Riffle gravel	.6	3.4	.2	--	--	--
Unnamed tributary	52-DC-789	Riffle sand	.01	.9	.01	--	--	--
Shoal Creek	52-DC-797	Riffle gravel	5.1	25.5	--	--	--	--
	52-DC-796	Riffle sand	.01	.7	.1	.01	--	--
	52-DC-795	Riffle gravel	--	52.7	--	--	--	--
	52-DC-798	Do.	--	12.5	--	--	--	--
Heads Creek	52-DC-801	Do.	--	12.5	--	--	--	--
	52-DC-802	Do.	--	4.6	--	--	.3	--
	52-DC-800	Do.	--	.6	--	--	--	--
	52-DC-799	Do.	--	2.7	--	--	--	--
	52-DC-804	Riffle sand	--	.5	--	--	--	--
	52-DC-803	Riffle gravel	--	6.5	--	--	--	--

Sand and clay, which predominate over gravel and silt in the flood-sediments along these streams, occur in a stratigraphic sequence similar to that in streams tributary to the Savannah River. Average percentages of alluvial sediments in the streams tributary to the Flint River are compared in the table below to those in tributaries to the Savannah River and in streams between the Savannah and Catawba Rivers:

Sediment	Percent of total sediment		
	Flint River area	Savannah River area	Area between the Savannah and Catawba Rivers
Clay	36	32	26
Silt	3	11	12
Sand	60	48	52
Gravel	1	9	10

Heavy minerals

Plate 3 shows the locations of the 25 samples collected in the Flint River area and the isograms drawn to show the distribution of heavy minerals. From Elkins Creek at Zebulon north to the southern tributaries to Shoal Creek west of Griffin, all streams contain 1 percent or more monazite in quartz-free concentrates. An east-trending 10 percent plateau includes Flat Creek and the heads of Elkins and Honey Bee Creeks. At the head of the lowermost tributary to Flat Creek, monazite reaches the

20 percent isogram, and on an unnamed stream south of Birch Creek, sample 52-DC-808 contains 20 percent monazite in the quartz-free concentrate. Riffle samples that have the highest tenors in monazite, ranging from 1.3 to 6.1 pounds per cubic yard of gravel or sand (table 10), are from the 10 percent monazite plateau or the high south of Birch Creek. One sample, 52-DC-810, which comes from the area between the 1 and 10 percent isograms, contains 1.6 pounds of monazite per cubic yard, but the other samples from that background area contain less than 1 pound of monazite to the cubic yard.

Zircon is rare and is restricted to three areas defined by 1 percent isograms: (1) a northeast-trending zone that follows the watershed between Elkins Creek and Birch Creek toward Zebulon; (2) an area at the head of Honey Bee Creek; and (3) a narrow zone that trends northeastward from the head of Flat Creek to the central part of Shoal Creek. At the head of Honey Bee Creek a 10 percent zircon isogram appears where the highest-tenor sample contains 0.8 pound of zircon per cubic yard of riffle sand.

Tourmaline and spinel occur with the zircon-bearing samples from Honey Bee Creek and at the head of Flat Creek. Tourmaline does not rise above 2 percent of the quartz-free concentrate, and spinel is 3 percent of the concentrate at both places.

Ilmenite and magnetite are the most abundant minerals in the concentrates. An ilmenite low defined by 20 percent isograms extends along the divide between Elkins and Birch Creeks to Griffin. East and west of the low, the ilmenite isograms rise to the 60 percent contour and locally reach an 80 percent contour. The largest areas above the 60 percent isogram are drained by Flat Creek where a sample has the highest individual tenor (64.4 pounds of ilmenite per cubic yard) in the Flint River area, and by Wildcat Creek where a sample has 39.1 pounds of ilmenite per cubic yard. Percentages of magnetite in the concentrate increase with a decrease in ilmenite, which leads to an 80 percent magnetite high to the west and northwest of Griffin.

Garnet is uncommon in the concentrates, and the samples that contain it are isolated at widely separated parts of the area; thus its distribution pattern is obscure.

With the exception of one sample near Zebulon, rutile is restricted to the high-ilmenite concentrates in the drainage basin of Flat Creek and the westernmost tributary to Shoal Creek. The isograms rise to a small 10 percent closure on Shoal Creek, but the sample at that closure contains only 0.1 pound of rutile per cubic yard of riffle sand. The largest amount of rutile is 1.5 pounds per cubic yard in a sample taken near the head of Flat Creek in an area between the 1 and 3 percent isogram.

The lower part of Birch Creek, Wildcat Creek, and the western tributaries of Heads Creek contain 1 percent epidote in quartz-free concentrates; in the remainder of the area epidote is less than 1 percent of the concentrate. Amphibole locally accompanies epidote in the concentrate, but it does not appear in the headwater samples used for plotting isograms.

A sample collected near Zebulon in an epidote-bearing area contains 3 percent sillimanite, and a sample from the head of Honey Bee Creek in an epidote-free area contains 1 percent sillimanite. No other samples have sillimanite, and none has kyanite or staurolite.

The typical monazite-bearing sample from the Flint River area consists of ilmenite and some magnetite and rutile. Zircon, garnet, tourmaline, spinel, epidote, and sillimanite appear locally in small amounts.

Spectrographic analyses of samples (table 4) from Flat, Shoal, and Heads Creeks were made on a sample containing more than 1 percent monazite and on two samples containing less than 1 percent monazite, mineralogical analyses of the samples are given in table 11. Niobium decreases in the sample that has no rutile but is the same in the two samples having 3 percent and a trace of rutile. The considerable difference in ilmenite makes no difference in the amount of niobium reported in the first two samples.

Table 11.--Mineralogical analyses of concentrates from streams in the drainage basin of the Flint River, Ga. [tr, trace; --, absent]

Mineral	Percent of concentrate		
	52-DC-790 Flat Creek	52-DC-795 Shoal Creek	52-DC-804 Heads Creek
Monazite	11	tr	tr
Ilmenite	64	31	37
Rutile	3	tr	--
Garnet	--	--	tr
Zircon	tr	--	--
Sillimanite	--	tr	--
Magnetite	11	57	54
Epidote	--	tr	1
Amphibole	--	--	tr
Hematite	--	--	2
Quartz	11	12	6

Appraisal

The Flint River area has only one stream along which the tenors in monazite are even moderately high. This is Flat Creek which drains monazite-bearing granite near Zetella, Ga., and contains 0.6 to 6.1 pounds of monazite per cubic yard in the riffle gravel. The flood plains along Flat Creek are narrow, discontinuous, and composed mainly of fine-grained sediments: clay is 40 percent of the total alluvium, sand is 53 percent, silt is 5 percent, and gravel is 2 percent. Although the coarser grained sand in the lower part of the sedimentary sequence might be a fair source for monazite, the combination of clayey overburden and discontinuous flood plains make Flat Creek unsuitable for placer mining.

Wildcat Creek and its two tributaries, Shoal Creek and Heads Creek, contain less than 1 percent monazite in concentrates from riffle gravel. The clay and probably most of the sand in the flood plains have less monazite than the riffle samples.

Sampling along Honey Bee and Elkins Creeks is meager, but the distribution of the monazite isograms shows that Honey Bee Creek heads in the 10 percent plateau in which Flat Creek flows. There is some suggestion that this plateau may continue downstream on Honey Bee Creek toward Potato Creek, but there is no evidence that the sedimentary sequence along Honey Bee Creek has a higher proportion of coarser detritus than other streams tributary to the Flint River. Most of Elkins Creek is southeast of the monazite-bearing area.

The Flint River area as defined by plate 3 is not suitable for placer mining, and, if the evidence from the Flint River area is combined with that from the nearby Chattahoochee River area (see following), it is evident that streams in western Georgia are a much poorer source for monazite than streams farther to the northeast in Georgia, South Carolina, and North Carolina.

Deposits in the drainage basin of the Chattahoochee River, Georgia

The two forks at the head of the Chattahoochee River, known as the Chestatee and Soque Rivers, rise at an altitude of 2,300 feet in the Blue Ridge of northern Georgia near the southern source of the Savannah River. From its head at the upper reaches of the Soque River, the Chattahoochee flows southwestward 220 miles to the boundary between Georgia and Alabama at the northwest corner of Harris County, Ga. (pl. 4). About 8 miles upstream from the northwest corner of Harris County the course of the Chattahoochee River changes and the river flows toward the south. It follows a southerly course for 45 miles to the north edge of the Coastal Plain sediments at Columbus, Ga.

The area covered by reconnaissance includes 660 square miles in Troup, Meriwether, and Harris Counties, Ga., in the eastern Piedmont about halfway between the head of the Chattahoochee River and the mouth of the Apalachicola River. Troup County and all but a small part of southern Meriwether County are areas of low relief. Local relief increases in Harris County toward Pine Mountain, a long, narrow ridge that rises 600 feet above the general level of the Piedmont to a maximum altitude of 1,400 feet. In the area north of Pine Mountain the tributaries to the Chattahoochee River flow southwestward from the divide shared with the Flint River.

LaGrange, the county seat of Troup County, is the largest community in the area. The good network of paved and unpaved roads in Troup County, in contrast to the poor system of roads in the two other counties, reflects the greater density of population in Troup County. LaGrange is served by the Seaboard Coast Line and by the Atlanta and West Point Railroad. Near the east and southeast parts of the area, rail service is provided by the Southern and Central of Georgia Railways.

The rocks that underlie the area have been divided into two units (Stose and Smith, 1939) separated by the Towaliga fault (Hewett and Crickmay, 1937, p. 31): (1) the gneisses, schists, and granite north of the fault; and (2) the Pine Mountain Series of metamorphosed sediments south of the fault. North of Pine Mountain, fine- to coarse-grained biotite gneiss, hornblende-biotite gneiss, muscovite schist, and biotite granite gneiss have well-developed foliation which trends N. 35° W. to N. 75° E. (Hewett and Crickmay, 1937, p. 26). The biotite granite gneiss, which is called the Snelson Granite by Hewett and Crickmay (1937, p. 26-27) and is shown as Lithonia type granite gneiss on the State geologic map (Stose and Smith, 1939), is coarser grained than the enclosing gneiss and schist and has a crude foliation marked by subparallel flakes of biotite. The contact between the Snelson Granite and gneiss and schist is gradational. Near the contact, bodies of granite and pegmatite have been widely injected into the gneiss and schist; commonly they are parallel to the foliation, but locally they cut across it.

The Snelson Granite is the most common rock in the northwestern half of Troup County. Southeast of Long Cane Creek and east of LaGrange, gneiss and small masses of Snelson Granite are the most common rocks. To the south the Towaliga fault can be traced many miles northeastward across Georgia as a narrow zone of sheared gneiss and granite. In the area shown on plate 4 the Towaliga fault extends from the mouth of Mountain Creek to the heads of the small streams from which samples 52-DC-749, 750, 752, and 756 were taken.

South of the Towaliga fault, the metamorphosed sediments of the Pine Mountain Series as used by Crickmay (1935) trend northeastward in a narrow belt across Harris County and Meriwether County. From the oldest to the youngest units the series, as described by Hewett and Crickmay (1937, p. 27-29), comprises the Sparks Schist, the Hollis Quartzite, and the Manchester Schist. The Sparks Schist is interlayered muscovite-biotite schist, biotite gneiss, and thin beds of quartzite, into all of which granitic material has been injected. The Hollis Quartzite is thin- to thick-bedded quartzite in which relics of sedimentary structure are preserved. The Manchester Schist, which is in contact with gneiss along the Towaliga fault, is a kyanitic muscovite schist that contains a layer of quartzite and some layers of garnet-hypersthene gneiss; south of Oak Mountain the schist is widely permeated by granitic material.

Because rocks north of the Towaliga fault are more highly metamorphosed than the rocks south of the fault, Hewett and Crickmay regard the northern group as the older. All the rocks are called Precambrian except cross-cutting diabase dikes which strike a few degrees west of north and are assigned to the Triassic.

Alluvium

Flood plains along most of the larger streams between Pine Mountain and the north boundary of Troup County are wider in the upper half of the streams than they are in the lower parts; but on smaller tributaries to the Chattahoochee River, like Wilsons Creek (52-DC-726), Maple Creek (52-DC-728), and Long Cane Creek, the flood plains widen progressively downstream. At 52-DC-714, about halfway between the head and the mouth of Yellowjacket Creek, the flood plains are 1,000 to 1,500 feet wide. Flood plains are 500 to 1,500 feet wide headward to 52-DC-722 and are 160 to 1,000 feet wide at 52-DC-721, on the west-flowing tributary, where the average width is 500 feet. At A-A', B-B', and C-C', near the mouth of the stream, the flood plains are 660, 800, and 1,000 feet wide. At the mouth of Flat Shoals Creek the flood plain is only 150 to 350 feet wide, and it is rarely wider than this below H-H'. Upstream from H-H', however, the flood plains attain a maximum width of 1,300 feet. Between O-O' and Q-Q' on Mountain Creek the flood plains are long, continuous, and are from 1,000 to 1,600 feet wide, but below Q-Q' the valley walls converge and the flood plains are narrow and discontinuous. The continuity of flood plains along the middle and upper reaches of Yellowjacket, Long Cane, Flat Shoals, and Mountain Creeks is good, but discontinuities are present toward the outlets of the streams. Characteristically the flood plains vary widely in width along the middle and lower parts of the streams and are uniform in width in the upper parts of the streams.

Table 12 shows that the depth of alluvial sediments in the Chattahoochee River drainage basin is similar to the depth of sediments elsewhere in the monazite belt: 10 to 18 feet of sediment is common in the middle parts of the streams; depths greater than 20 feet are rare but are reached locally, especially toward the mouths of the streams. The average depth of alluvium is 12.6 feet at 41 of the 43 auger holes drilled in the area. More holes were drilled in the upper reaches of Mountain Creek and its tributaries than were sunk in like parts of the other streams, with the result that the average depth of alluvium at the holes on Mountain Creek is less than the average depth of sediment at holes in the flood plains along streams farther north on the Piedmont. However, the maximum depth of sediment in the large flood plains near the center of Mountain Creek is less than the maximum depths of alluvium in the large flood plains on the other streams, and the actual depth of sediment along Mountain Creek is probably less than it is in the valleys of the other streams. Along the lines of auger drill holes shown on figure 5, the average and maximum depths of sediment at each stream are:

Stream	Line of holes	Number of holes drilled	Average depth of alluvium (feet)	Maximum depth of alluvium (feet)
Mountain Creek	M-M' through R-R'	15	9.0	15.0
House Creek	L-L'	2	16.5	20.0
Flat Shoals Creek	H-H' through K-K'	6	17.1	25.0
Long Cane Creek	E-E' through G-G'	7	12.6	17.0
Yellowjacket Creek	A-A' through C-C'	9	13.9	18.0
Chattahoochee River	D-D'	2	14.2	17.0

Table 12.--Drilling data, Chattahoochee River drainage basin, Troup and Harris Counties, Ga. [See pl. 4]

Section	Hole	Depth (ft)	Description of sediment. Terms are those defined in Overstreet and others, 1968, p. 52-53.
Yellowjacket Creek			
A-A'	D583	0-1 1/2	Red-brown clayey silt
		1 1/2-9	Sandy clay, sand medium, upper 5 ft yellow, grades to mottled gray and yellow
		9-11 1/2	Blue-white clayey medium-coarse sand
		11 1/2-13	Gray-white coarse sand, gravelly at base
		13-14	Brown saprolite
	D584	0-1	Dark-brown sandy silt, sand fine
		1-9 1/2	Orange silty clay
		9 1/2-14	Greenish-brown biotite schist saprolite
B-B'	D582	0-1/2	Dark-red-brown micaceous clayey silt
		1/2-10	Micaceous silty clay, upper 4 ft orange, grades to light yellow-brown
		10-12	Light-brown micaceous silty fine sand
		12	Unweathered bedrock
	D581	0-1/2	Dark-brown to red clayey silt
		1/2-5	Clay, upper 4 ft mottled gray, yellow, and red-brown, grades to gray and green

Table 12.--Drilling data, Chattahoochee River drainage basin, Troup and Harris Counties, Ga. [See pl. 4], continued

Section	Hole	Depth (ft)	Description of sediment. Terms are those defined in Overstreet and others, 1968, p. 52-53.
		5-8 1/2	Greenish-brown sandy clay, sand medium-coarse
		8 1/2-15	White coarse sand grades to yellow-brown granule sand at 12
		15-19	Brown biotite schist saprolite
	D580	0-1/2	Red clayey silt
		1/2-6	Mottled gray and yellow silty clay
		6-10	Blue-gray micaceous sandy clay, sand fine
		10-12	Brown medium-coarse sand, gravelly at base
		12-14	Brown biotite schist saprolite
	D579	0-1	Red micaceous slayey silt
		1-5	Brown micaceous sandy silt, sand medium
		5-14 1/2	Sandy clay, sand medium, upper 5 1/2 ft mottled gray and yellow, grades to mottled gray and dark green, grades to gray micaceous clayey fine sand at 11, grades to brown at 13
		14 1/2	Unweathered bedrock
C-C'	D576	0-5	Red-brown silty clay
		5-10 1/2	Yellow-brown micaceous clayey silt

Table 12.--Drilling data, Chattahoochee River drainage basin, Troup and Harris Counties, Ga. [See pl. 4], continued

Section	Hole	Depth (ft)	Description of sediment
		10 1/2-18	Brown clayey medium-coarse sand, grades to granule sand at 15, grades to pebbly sand at 17
		18-21	Brown biotite schist saprolite
	D577	0-4 1/2	Red clay
		4 1/2-17	Brown sandy clay, sand medium, grades to medium-coarse sand at 7 1/2, grades to gravelly coarse sand at 15
		17-19	Brown biotite schist saprolite
C-C'	D578	0-1/2	Brown micaceous silty clay
		1/2-6 1/2	Clay, alternate layers gray and yellow
		6 1/2-14	Gray micaceous clayey silt, grades to blue-gray micaceous silty medium-fine sand at 7 1/2, grades to coarse sand at 10, grades to pebble-cobble gravel at base
		14	Brown biotite schist saprolite
Chattahoochee River			
D-D'	D575	0-3 1/2	Yellow-brown medium-fine sand
		3 1/2-17	Red-brown micaceous sandy silt, sand fine, grades to brown micaceous clayey silt at 10
		17	Boulder or unweathered bedrock

Table 12.--Drilling data, Chattahoochee River drainage basin, Troup and Harris Counties, Ga. [See pl. 4], continued

Section	Hole	Depth (ft)	Description of sediment
	D574	0-11 1/2	Reddish-brown clayey silt, grades to micaceous silty fine sand at 9 1/2
		11 1/2-14	Brown biotite schist saprolite
E-E'	D571	0-6	Road fill
		6-7 1/2	Dark-brown micaceous carbonaceous clay
		7 1/2-10 1/2	Light-gray clayey medium-coarse sand
		10 1/2-13	Mottled gray and yellow sandy clay, sand medium fine
		13-23	Yellowish-white coarse sand, grades to pebbly sand at 21
		23-24	Dark-green hornblende gneiss saprolite
	D572	0-7	Road fill
		7-8	Dark-brown sandy clay, sand medium coarse
		8-12	Light-gray carbonaceous clayey silt
		12-14 1/2	Blue-green sandy clay, sand fine, grades to blue-white clayey medium-fine sand at 13 1/2
		14 1/2-24	Yellowish-white medium-coarse sand, grades to gravelly sand at 21
		24-26	Gray-green hornblende gneiss saprolite
		26-29	Brown biotite schist saprolite

Table 12.--Drilling data, Chattahoochee River drainage basin, Troup and Harris Counties, Ga. [See pl. 4], continued

Section	Hole	Depth (ft)	Description of sediment
F-F'	D573	0-3	Road fill
		3-5	Clayey medium sand, alternate layers of gray and yellow
		5-9	Sandy clay, sand medium, alternate layers of green and yellow
		9-13 1/2	Dark-blue-gray carbonaceous clay
		13 1/2-15	Gray medium sand
		15-19	Brown biotite schist saprolite
G-G'	D564	0-5	Road fill
		5-10	Gray and brown sandy clay, sand fine
		10-15	Gray-white coarse sand, gravelly at base
		15-19	Dark-blue-green hornblende gneiss saprolite
	D563	0-3	Road fill
		3-11 1/2	Gray clayey fine sand, grades to white medium-coarse sand at 9 1/2, grades to pebbly sand at 11
		11 1/2-14	Green to brown biotite schist saprolite
	D562	0-3 1/2	Red sandy clay
		3 1/2-9	Yellow clay
		9-15	Gray-yellow clayey medium-fine sand, grades to pebbly coarse sand
		15-19	Brown to green biotite schist saprolite

Table 12.--Drilling data, Chattahoochee River drainage basin, Troup and Harris Counties, Ga. [See pl. 4], continued

Section	Hole	Depth (ft)	Description of sediment
	D565	0-4	Red sandy clay
		4-9	Yellow-brown clay, lens of gravelly clay at 5
		9-13	Yellow biotite schist saprolite
Flat Shoal Creek			
H-H'	D570	0-16	Red-brown medium-coarse sand, lens of peat at 13 1/2, 1-2 in. layers of silt 10-14
		16-19	Blue-gray medium-coarse sand
		19	Unweathered bedrock
	D569	0-14	Red-brown medium-coarse sand, layer of red-brown silty clay 6-6 1/2, grades to gravel at 12 1/2
		14	Unweathered biotite schist
I-I'	D566A	0-3	Dark-brown sandy silt, sand medium
		3-4 1/2	Red-brown clayey
		4 1/2-7 1/2	Yellow-brown sandy clay, sand medium, gravelly at base
		7 1/2-9	Green biotite schist saprolite
	D567	0-4	Silty medium-fine sand, upper 2 1/2 ft brown, grades to yellow-brown

Table 12.--Drilling data, Chattahoochee River drainage basin Troup and Harris Counties, Ga. [See pl. 4], continued

Section	Hole	Depth (ft)	Description of sediment
		4-8 1/2	Reddish-brown sandy silt, sand fine
		8 1/2-18	Light-brown clayey fine sand, grades to medium-coarse sand at 13, gravelly at base
		18-19	Biotite schist saprolite
J-J'	D568	0-2 1/2	Red clayey medium sand
		2 1/2-6 1/2	Brown micaceous silty clay, grades to gray carbonaceous silty clay at 3 1/2, grades to carbonaceous sandy clay, sand medium, at 4 1/2
		6 1/2-8 1/2	Clayey fine sand, alternate layers of gray and yellow
		8 1/2-11 1/2	Yellowish-white medium sand, grades to granule sand at 10
		11 1/2-16	Blue to brown micaceous silty clay
		16-21	Yellow-brown medium sand, grades to pebble-cobble gravel at 19 1/2
		21-24	Brown biotite schist saprolite
K-K'	D561	0-8 1/2	Brown medium sand
		8 1/2-11	Red-brown sandy silt, sand fine
		11-12 1/2	Red-brown medium-coarse sand
		12 1/2-15	Light-gray carbonaceous clay

Table 12.--Drilling data, Chattahoochee River drainage basin Troup and Harris Counties, Ga. [See pl. 4], continued

Section	Hole	Depth (ft)	Description of sediment
		15-25	Granule sand, upper 2 ft brown, grades to gray, lens of peat 17 1/2-18, grades to pebble-cobble gravel at 22
		25	Boulder or unweathered bedrock
House Creek L-L'	D560	0-8	Red clayey medium-coarse sand, grades to gravelly sand at 2
		8-20	Gray carbonaceous clayey medium-fine sand, grades to gray carbonaceous clay at 9, grades to gray carbonaceous medium-coarse sand at 13 1/2, grades to pebble-cobble gravel at 18
		20-24	Gray to yellow-brown biotite schist saprolite
	D559	0-10	Brown clayey medium-coarse sand, grades to dull-red sandy clay, sand medium, at 2 1/2
		10-13	Yellow-gray sandy clay, sand medium
		13	Sheet of pebble gravel
		13-14	Black biotite schist saprolite
Mountain Creek			
M-M'	D545	0-1 1/2	Brown silty medium-coarse sand
		1 1/2-2 1/2	Gray carbonaceous sandy clay, sand fine

Table 12.--Drilling data, Chattahoochee River drainage basin Troup and Harris Counties, Ga. [See pl. 4], continued

Section	Hole	Depth (ft)	Description of sediment
		2 1/2-5	Gray and yellow micaceous clayey silt
		5-6 1/2	Gray pebbly coarse sand grades to gravel at base
		6 1/2-14	Orange muscovite schist saprolite
M-M'	D544	0-2	Mottled gray and yellow gravelly clay, granule-pebble gravel
		2-19	Biotite schist saprolite, upper 1 1/2 ft mottled white and brown grades to green-gray, grades to dark brown at 7
N-N'	D548	0-1	Red clay
		1-3	Brown sandy silt, sand fine
		3-5 1/2	Gray clayey silt
		5 1/2-10	Blue-gray sandy clay, sand fine, grades to clayey coarse sand at 7, grades to clayey pebbly sand at 8 1/2
		10-19	Pale-green saprolite
	D547	0-1 1/2	Red clayey medium sand
		1 1/2-7	Yellow micaceous clayey silt
		7-10 1/2	Pebble-cobble gravel, matrix of light-yellowish-brown clayey sand
		10 1/2-19	Dark-brown saprolite

Table 12.--Drilling data, Chattahoochee River drainage basin Troup and Harris Counties, Ga. [See pl. 4], continued

Section	Hole	Depth (ft)	Description of sediment
	D546	0-8 1/2	Silty medium-coarse sand, upper 3 1/2 ft yellow-red, grades to gray, grades to pebbly coarse sand at 5, grades to sandy pebble gravel at 6
		8 1/2-14	Biotite schist saprolite, upper 4 ft green, grades to red
0-0'	D550	0-3	Red-brown silty medium-coarse sand
		3-4 1/2	Gray silty fine sand
		4 1/2-7	Yellow medium sand
		7-12	Gray micaceous silty fine sand, grades to carbonaceous medium sand at 8 1/2, grades to pebble-cobble gravel at 11
		12-14	Yellow saprolite
	D549	0-1	Brown clayey silt
		1-2	Yellow-brown granule sand
		2-7 1/2	Gray carbonaceous silty medium-fine sand, grades to coarse sand at 5, grades to pebble-cobble gravel at 7
		7 1/2-14	Saprolite, upper 3 1/2 ft light green, grades to yellow-white

Table 12.--Drilling data, Chattahoochee River drainage basin, Troup and Harris Counties, Ga. [see pl. 4], continued

Section	Hole	Depth (ft)	Description of sediment
P-P'	D554	0-1/2	Red sandy silt, sand medium-fine
		1/2-12 1/2	Gray carbonaceous clayey silt, grades to yellow silty clay at 3, grades to yellow sandy clay, sand fine, at 4 1/2, grades to granule sand at 9, grades to pebble gravel at 10 1/2
		12 1/2-14	Yellow-brown saprolite
	D553	0-5 1/2	Red-brown clayey silt, grades to gray carbonaceous sandy silt, sand fine, at 2 1/2, grades to carbonaceous clayey silt at 4
		5 1/2-7	Blue-gray sandy silt, sand fine
		7-10	Gray medium-coarse sand, grades to pebble-cobble gravel at 9
		10-14	Green, gray, and brown saprolite
	D552	0-3 1/2	Dark-red-brown silty clay
		3 1/2-4 1/2	Dark-gray-brown sandy clay, sand medium
		4 1/2-11 1/2	Light-gray clayey medium-coarse sand, grades to granule sand at 8 1/2, grades to pebble-cobble gravel at 10
		11 1/2-14	Blue-green saprolite

Table 12.--Drilling data, Chattahoochee River drainage basin, Troup and Harris Counties, Ga. [See pl. 4], continued

Section	Hole	Depth (ft)	Description of sediment
	D551	0-1	Brown clayey medium sand
		1-4 1/2	Yellow sandy clay, sand medium, grades to clayey coarse sand at 2 1/2, grades to pebble-cobble gravel, matrix of clayey coarse sand at 3
		4 1/2-9	Orange-brown saprolite
Q-Q'	D555	0-1	Dark-brown sandy clay, sand medium
		1-7 1/2	Yellow silty clay
		7 1/2-11	Gray sandy clay, sand fine
		11	Sheet of pebble gravel
		11-14	Purple biotite schist saprolite
	D556	0-2	Red clay and medium sand
		2-5 1/2	Gray and brown micaceous silty clay
		5 1/2-15	Light-gray medium-fine sand, grades to pebbly granule sand at 12
		15-19	Purple and brown biotite schist saprolite
	D557	0-3 1/2	Red micaceous clayey silt
		3 1/2-7 1/2	Yellow sandy clay, sand medium, grades to gravelly clay at 7
		7 1/2-14	Dark-green biotite schist saprolite

Table 12.--Drilling data, Chattahoochee River drainage basin, Troup and Harris Counties, Ga. [see pl. 4], continued

Section	Hole	Depth (ft)	Description of sediment
R-R'	D558	0-4	Brown gravelly silt
		4-5 1/2	Gravel
		5 1/2-9	Green biotite schist saprolite

The alluvial sediments form a sequence that grades downward from silt and clay at the top of the flood plain to coarse sand and gravelly sand at the bottom. This is similar to the sequences observed along the Flint, Oconee, and Savannah Rivers, but coarse-grained debris is less common than it is farther to the northeast between the Savannah and Catawba Rivers. The amount of coarse-grained sediment decreases from 11 percent of the sediment along Mountain Creek to 4 percent along Flat Shoals Creek, and to less than 1 percent along Long Cane and Yellowjacket Creeks:

Stream	Relative amount of the sediments (percent)			
	Gravel	Sand	Silt	Clay
Mountain Creek	11	38	23	28
House Creek	6	47	tr	47
Flat Shoals Creek	4	76	5	15
Long Cane Creek	tr	52	5	43
Yellowjacket Creek	tr	34	12	54
Chattahoochee River	tr	19	81	tr
Average for area on the Chattahoochee River	4	47	15	34
Average for area on the Flint River	1	60	3	36
Average for area on the Oconee River	3	41	24	32
Average for area between Savannah and Catawba Rivers	10	52	12	26

Table 13.--Tenors of sediments in the drainage basin of the Chattahoochee River, Ga.--Continued

Stream	Sample number	Sediment	Pounds per cubic yard						
			Monazite	Ilmenite	Rutile	Zircon	Garnet	Kyanite	Sillimanite
Long Cane Creek--Continued	52-DC-735	Riffle sand	--	6.8	--	--	--	--	--
	52-DC-734	Riffle gravel	--	2.9	--	--	--	--	--
	52-DC-732	Riffle sand	--	.03	--	--	tr	--	--
	52-DC-733	Do.	tr	.1	--	--	--	--	--
	52-DC-730	Riffle gravel	--	17.4	--	--	1.3	--	.6
	52-DC-731	Bank silt	.01	.3	--	.01	.01	--	--
Maple Creek	52-DC-728	Riffle gravel	--	4.6	--	--	.2	--	--
	52-DC-729	Do.	--	16.2	--	--	.7	--	--
Unnamed tributary	52-DC-727	Do.	1.3	23.0	--	--	.7	--	--
Wilson Creek	52-DC-726	Do.	--	6.8	--	--	.6	--	--
Yellowjacket Creek	52-DC-720	Riffle sand	.6	46.0	--	--	--	--	--
	52-DC-719	Riffle gravel	--	30.2	--	--	--	--	--
	52-DC-714	Riffle sand	--	.02	--	--	--	--	--
	52-DC-713	Do.	.02	.5	--	.03	.02	--	--
	52-DC-711	Riffle gravel	--	2.9	--	--	--	--	--
	52-DC-710	Do.	2.6	20.6	--	.6	.6	--	--
Flat Creek	52-DC-721	Do.	.4	12.1	.2	--	.7	--	--
	52-DC-722	Do.	--	2.4	--	--	.2	--	--
	52-DC-718	Riffle sand	--	.4	--	--	.01	--	.01
Beach Creek	52-DC-725	Do.	.08	2.5	--	.08	--	--	--
	52-DC-724	Do.	--	2.7	--	.09	--	--	--
	52-DC-723	Do.	--	.08	--	--	.02	--	.02
	52-DC-715	Riffle gravel	--	18.8	--	--	--	--	--
	52-DC-717	Do.	--	8.0	--	--	.8	--	--
	52-DC-716	Do.	.2	1.6	--	--	--	--	--
	52-DC-712	Do.	.07	1.1	--	--	--	--	--
Pine Mountain terraces	52-DC-754	Terrace gravel	tr	.1	.01	.01	.02	--	tr
	52-DC-753	Do.	--	.5	.4	.06	--	--	--

Three features of the alluvium in these flood plains combine to make the area unfavorable for monazite mining: (1) the upper half of the sedimentary sequence is clay and silt, (2) gravel is scant, and (3) much of the sand is fine grained.

Small deposits of fluvial gravel composed of angular to sub-angular cobbles of quartzite and a few rounded cobbles of granite (weathered to a depth of 3 or 4 inches) embedded in a thin veneer of residual soil rest on Hollis Quartzite at flat places on the top of Pine Mountain. On the side of the mountain at altitudes between 850 and 950 feet, patches of unconsolidated sand and clay rest on the saprolite of Manchester Schist and on weathered Hollis Quartzite. Kaolinite and bauxite have been mined from one of the patches of clay. The ages of both types of deposit are obscure, but the sand and clay is younger than the gravel at the top of the mountain. Hewett and Crickmay (1937, pl. 1) suggest that the gravel at the top of Pine Mountain is Tertiary(?).

Heavy minerals

Most of the samples collected in Troup, Harris, and Meriwether Counties are from streams that drain gneiss, schist and Snelson Granite north of the Towaliga fault; only a few samples are from streams that flow over rocks of the Pine Mountain Series or from deposits of terrace gravel on Pine Mountain (table 13).

The heavy-mineral concentrates from the riffle samples can be grouped into three suites which are respectively characteristic of: (1) the area underlain chiefly by Snelson Granite in northwestern and central Troup County, (2) the area southeast of Long Cane Creek and east of La Grange in which gneiss and schist are dominant, and (3) the area south of the Towaliga fault where the Manchester Schist and Hollis Quartzite crop out. Mineralogical differences are shown by the isograms on Pl. 4 and are summarized in table 14.

Monazite is absent from 28 percent of the riffle samples; most of the monazite-free samples are from Long Cane and Maple Creeks and from the northwest-flowing tributaries to Yellowjacket Creek. These streams drain areas underlain mainly by Snelson Granite and subordinate amounts of gneiss and schist. At the few places where monazite is in riffle sediments in streams draining the Snelson Granite, like the middle and lower reaches of Yellowjacket Creek and the small tributaries to the Chattahoochee River between Yellowjacket and Long Cane Creeks, it rarely exceeds 1 percent of the concentrate. In these streams monazite ranges from 0.1 to 0.4 pound per cubic yard of riffle gravel, except at 52-DC-726 and 52-DC-710 where it reaches 1.3 and 2.6 pounds per cubic yard. In the upper part of Mountain Creek and in the tributaries to Flat Shoals Creek near the Harris County-Meriwether County line, where Manchester Schist and Hollis Quartzite crop out, the riffle sediment is generally barren of monazite, although rarely it contains as much as 0.2 pound of monazite per cubic yard.

Table 14. Relation of heavy minerals to source rocks in the drainage basin of the Chattahoochee River, Ga.

Mineral	Source rocks: Chiefly Snelson Granite	Chiefly gneiss and schist	Manchester Schist and Hollis Quartzite
Monazite	Rare	Common	Absent to rare
Zircon	do.	do.	Rare
Xenotime	Absent	Rare	Absent
Spinel	do.	do.	do.
Tourmaline	Rare	do.	Rare
Ilmenite	Common	Abundant	Common
Rutile	Absent	Common	Locally abundant
Magnetite	Abundant	Absent to common	Rare
Garnet	Rare	Rare	do.
Sillimanite	do.	do.	do.
Kyanite	Absent	Absent	Abundant
Epidote	Common	Rare	Absent
Amphibole	do.	do.	do.
Staurolite	Rare	Locally abundant	Rare

The best source of monazite is the area between Long Cane Creek and the Towaliga fault where the predominant rock is gneiss and schist. Over most of this area monazite forms 1 to 6 percent of the concentrate and locally it rises in abundance to 12 percent of the concentrate, but even in this area the tenor of most of the riffle sediments is between 0.1 and 0.5 pound of monazite per cubic yard. The maximum tenor attained is 2.8 pounds of monazite per cubic yard of riffle gravel at 52-DC-771.

Ilmenite commonly forms 20 to 40 percent of the concentrate from riffle sediments in streams whose distributive provinces are underlain chiefly by Snelson Granite, Manchester Schist, and Hollis Quartzite. In the area where gneiss and schist have the widest distribution, the concentrates from riffle sediments contain 60 to 80 percent ilmenite. Along most of the length of the two boundaries between the area of gneiss and schist and the areas of Snelson Granite and the Pine Mountain Series, the ilmenite isograms form two narrow zones in which the contours rise in value toward the gneiss and schist from 40 to 80 percent. Thus, much of the area underlain by gneiss and schist is a plateau bounded on the northwest and southeast by the 80 percent ilmenite isogram. Near the north edge of this plateau the highest tenor in ilmenite, 60.2 pounds per cubic yard, is attained at 52-DC-771 where monazite is also at its maximum tenor. Of the 16 samples from riffle gravel that contain more than 10 pounds of ilmenite per cubic yard of sediment, 10 are from areas bounded by the 80 percent ilmenite isogram; the others are scattered among the areas enclosed by lower value isograms. Nine samples of riffle gravel contain 2.0 pounds or less of ilmenite per cubic yard. Two of these are from areas where the concentrate contains 60 percent of more ilmenite; the remainder are from the areas where ilmenite makes up less than 40 percent of the concentrate.

Rutile is absent from the areas underlain by Snelson Granite. It makes up 1 to 3 percent of the concentrate in the southwestern part of the area where gneiss and schist are most common, and it locally forms 9 percent of the concentrate from riffle sediments in streams draining the Manchester Schist and Hollis Quartzite. Where present, rutile rarely exceeds 0.3 pound per cubic yard of riffle gravel; the highest tenor sample, 52-DC-768 from the area of gneiss and schist, contains 1.3 pounds of rutile per cubic yard.

The distribution of and tenors in zircon are similar to those of monazite, but zircon is not as uncommon in streams draining the Pine Mountain Series as is monazite. The main sources of zircon are southeast of the Snelson Granite in the area of gneiss and schist where zircon froms 1 to 5 percent and locally 15 percent of the concentrate. Many of the high-value zircon isograms coincide with high-value monazite isograms. From the area of Snelson Granite a few samples contain 1 to 3 percent zircon, but most are barren. Concentrates from alluvium along streams that drain the Manchester Schist and Hollis Quartzite locally contain 1 to 5 percent zircon. The average tenor of riffle sediments is 0.3 pound of zircon per cubic yard, and the maximum is 3.4 pounds per cubic yard at 52-DC-771 where monazite also reaches its highest tenor.

Only one-third of the samples contain garnet, but it is sporadically distributed in small amounts in sediments derived from each of the three groups of rock. At the mouth of Long Cane Creek and near the middle of House Creek, riffle gravel contains 1.3 and 1 pound of garnet, respectively, per cubic yard; elsewhere the sediment has less than 1 pound of garnet to the cubic yard.

Kyanite is absent from concentrates collected on streams that drain the rocks north of the Towaliga fault, but it is a common constituent of concentrates from streams rising in the Manchester Schist. The headwater tributaries to Sulfur Creek, which have their sources on the north side of Pine Mountain, and the head and southern tributaries to Mountain Creek, which rise on the same side of the mountain, are the only streams in the area that contain kyanite. In the northern tributaries to Mountain Creek, such as the one from which 52-DC-784 was taken and which flow over gneiss and schist, kyanite is absent. The kyanite-bearing concentrates are notably low in monazite, and the concentrate with the maximum tenor in kyanite, 13.7 pounds per cubic yard of riffle gravel, has no monazite.

Most of the sediment contains no sillimanite, but small amounts are in a few concentrates from the southwestern part of the area, and it is also sporadically distributed in several concentrates from the south-central and east-central parts of the area. It is associated with kyanite in sediments in the upper reaches of Mountain Creek, where it was probably derived from the Manchester Schist. Most of the sillimanite-bearing samples come from areas underlain by gneiss and schist, but a few, including the sample with the maximum tenor of 0.6 pound per cubic yard at the lower end of Long Cane Creek, come from areas of Snelson Granite.

The relative abundance of magnetite complements that of ilmenite: magnetite rises to 80 percent of the concentrate in the areas of Snelson Granite where ilmenite diminishes to less than 20 percent of the concentrate. Low percentages of magnetite are common in the areas of gneiss and schist and in the southwestern part of the Pine Mountain Series. Epidote is absent from alluvium derived from the Pine Mountain Series, is rare in detritus from gneiss and schist, and makes up 1 to 10 percent of the heavy minerals in sediments from the Snelson granite. Amphibole is commonly associated with epidote in the concentrates and has a distribution similar to that of the epidote. Xenotime, spinel, tourmaline, and staurolite are rare; in one sample from the head of Beach Creek, staurolite rises in abundance to 20 percent of the concentrate.

A concentrate from the area of gneiss and schist drained by Flat Shoals Creek is typical of riffle gravel in this part of the monazite belt. Such a concentrate weighs about 12 pounds per cubic yard of sediment and consists of:

Mineral	Percent of concentrate
Ilmenite	85
Monazite	5
Zircon	5
Rutile	1
Magnetite	2
Garnet, kyanite, and sillimanite	2

This assemblage is similar to the suites of heavy minerals from the monazite belt in the drainage basins of the Savannah and Saluda Rivers in South Carolina (D. W. Caldwell, written commun., 1969). An assemblage of heavy minerals similar to the concentrates associated with the northwestern margin of the monazite belt in the area between the Savannah and Catawba Rivers is found in the lower part of Yellowjacket Creek, where an average concentrate from riffle gravel weighs about 60 pounds per cubic yard and consists of:

Mineral	Percent of concentrate
Magnetite	60
Ilmenite	35
Monazite	1
Epidote	2
Amphibole	2
Zircon, garnet, and staurolite	tr

The two concentrates made from gravel in the Tertiary(?) terraces on Pine Mountain (52-DC-753 and 52-DC-754) and a sample from the unconsolidated sand and clay near the base of the mountain (52-DC-750) have the following composition:

Mineral	Percent of concentrate		
	52-DC-753	52-DC-754	52-DC-750
Magnetite	tr	tr	tr
Ilmenite	54	71	61
Monazite	--	1	12
Garnet	tr	10	tr
Zircon	6	8	12
Sillimanite	--	1	tr
Kyanite	--	--	6
Staurolite	--	4	1
Amphibole	--	tr	tr
Tourmaline	--	tr	--
Hematite	tr	2	3
Rutile	40	3	5

The three concentrates are small. Sample 52-DC-753, which was taken from the top of Dowdell Knob on Pine Mountain (Hewett and Crickmay, 1937, pl. 1), is equivalent to 1 pound of heavy minerals per cubic yard of gravel; 52-DC-754, which is from a deposit at the top of the mountain near the junction of Georgia routes 190 and 85 about 3 miles south of Warm Springs, is equivalent to 0.1 to 0.2 pound per cubic yard of gravel. Sample 52-DC-750 was taken from rounded gravel exposed in a roadcut near the head of Sulfur Creek 5 miles west of Warm Springs; it is equivalent to 2.5 pounds of heavy minerals per cubic yard of gravel.

Spectrographic analyses (table 4) were made on four concentrates which have the following mineralogical composition (table 15):

Table 15.--Mineralogical analyses of concentrates from the drainage basin of the Chattahoochee River, Ga.

[tr, trace; --, absent]

Mineral	Percent of concentrate			
	52-DC-710 Yellowjacket Creek	52-DC-730 Long Cane Creek	52-DC-777 Flat Shoals Creek	52-DC-783 Mountain Creek
Monazite	4	tr	4	2
Xenotime	--	--	tr	--
Ilmenite	32	27	77	70
Rutile	--	--	2	1
Garnet	1	2	tr	2
Zircon	1	tr	3	3
Sillimanite	--	1	--	3
Kyanite	--	--	--	11
Spinel	--	tr	--	1
Staurolite	tr	tr	--	1
Epidote	1	tr	--	--
Amphibole	1	2	--	tr
Tourmaline	--	tr	tr	2
Magnetite	55	53	2	tr
Quartz	4	11	12	4
Hematite	1	4	--	--

A trace of tin appears in the concentrate from Mountain Creek, and traces of niobium are in each of the four samples, but none of the concentrates is an ore for either element.

Appraisal

The monazite-bearing area in the drainage basin of the Chattahoochee River, as defined by Plate 4 has no monazite placers. Because of the decrease in the proportion of gravel to other alluvial sediments northward from Mountain Creek, and because of the decrease in the tenor of riffle gravel to the north and south of Flat Shoals Creek, economic placers of any scale have not formed in the area.

Although large-volume flood plains are along Yellowjacket, Long Cane, Flat Shoals, and Mountain Creeks, the combination of a high proportion of fine-grained sediment and scarcity of monazite produces ground of extremely low average tenor. Samples of riffle gravel, which commonly are three or four times as rich in monazite as is the top-to-bottom average of the flood-plain sediments, do not exceed 2.8 pounds of monazite per cubic yard and average only 0.5 pound of monazite per cubic yard. The average tenor of alluvium along Flat Shoals Creek, which drains the best source area for monazite, is estimated at about 0.2 pound per cubic yard, and the flood plains along Yellowjacket, Long Cane, and Mountain Creeks are estimated to contain less than 0.1 pound of monazite per cubic yard of alluvium.

Other sources of monazite

Deposits of monazite in bedrock

None of the crystalline rocks in the belt is an ore of monazite, although many of the rocks are monazite-bearing. The average tenor of bedrock is about 0.06 pound of monazite per cubic yard, but wide variations from the average are common (Overstreet, 1967, p. 201). Many of the logs of churn-drill holes sunk by the U.S. Bureau of Mines in the flood plains in or adjacent to the western monazite belt show tenors for saprolitic bedrock that are much higher than this. It seems unlikely that these high tenors in some samples of saprolite can be attributed to a natural settling of detrital monazite into the upper 2 or 3 feet of the saprolite in a manner analogous to the downward migration of gold into the joints and foliation of bedrock underlying placers. The specific gravity of monazite is much less than that of gold, and the saprolite is commonly dense and clayey at its contact with flood-plain sediments. Doubtless imperfect cleaning allowed some detrital monazite to be carried into the sample cut from the saprolite. The logs of 46 holes have been dropped from the tabulation (table 16) because contamination by detrital monazite is obviously great. Generally the type of saprolite cannot be identified from the slurry into which it is churned; hence in table 16 only the areas drilled are shown and the kinds of rocks are not named.

Table 16. Monazite in saprolite of crystalline rocks underlying the flood plains of streams in western North and South Carolina

[Data supplied in 1951-53 by R. F. Griffith and L. A. Hansen, U.S. Bureau of Mines]

Stream	Monazite (lbs/cu yd)	Number of holes for weighted average
South Muddy Creek, McDowell County, N.C.	0.21	11
Silver Creek, Burke County, N.C.	.26	4
Hall Creek, Burke County, N.C.	.28	3
Catawba River, Burke County, N.C.	.07	3
Buffalo Creek, Cleveland County, N.C.	.34	1/ 13
Knob Creek, Cleveland County, N.C.	.43	1/ 12
Wards Creek, Cleveland County, N.C.	.40	9
Duncans Creek, Cleveland County, N.C.	.47	1/ 4
Hinton Creek, Cleveland County, N.C.	.27	13
First Broad River, Cleveland County, N.C.	.30	1/ 16
Sandy Run, Rutherford County, N.C.	.46	1/ 17
Catheys Creek, Rutherford County, N.C.	.52	4
Cane Creek, Rutherford County, N.C.	.23	3
Broad River, Cherokee County, S.C.	.10	8
Thicketty Creek, Cherokee County, S.C.	.07	8
North Tyger River, Spartanburg County, S.C.	.32	1/ 10
North Rabon Creek, Laurens County, S.C.	.24	1/ 6
South Rabon Creek, Laurens County, S.C.	.18	1/ 6
Big Generostee Creek, Anderson County, S.C.	.09	1/ 9
Weighted average	.29	159

1/ Additional holes of higher average tenor are discussed in the text.

Saprolite in the 46 poorly cleaned churn-drill holes appears to contain from 0.66 to 1.83 pounds of monazite per cubic yard (Griffith, R. F., written commun, 1951; Hansen, L. A., written commun. 1952-1953):

Stream	Monazite (lbs/cu yd)	Number of holes for weighted average
Buffalo Creek	1.41	4
Knob Creek	1.83	11
Sandy Run	1.20	11
Duncans Creek	1.06	2
First Broad River	.82	3
North Tyger River	.79	6
North Rabon Creek	.96	6
South Rabon Creek	1.57	1
Big Generostee Creek	.66	2

Equivalent tenors are unreported in detailed studies of the amount of monazite in saprolite (Mertie, 1953, p. 28; Overstreet, Yates, and Griffitts, 1963, table 1), which show that in the western Piedmont of the southeastern States the bedorck is not an ore of monazite.

Eluvial placers

Eluvial placers are concentrations of monazite and other heavy minerals in residual soil and colluvium. Residual soil consists of clayey sand and quartz fragments that have accumulated in place, mainly on divides, from the disintegration of saprolite and, rarely, of unweathered rock. Texture and strucutre of the saprolite are not preserved, and the chief clue to the parent rock of the residuum is the contained heavy minerals. The residual soil commonly forms mantles a few inches to 7 feet thick on interstream areas, and it grades downslope into colluvial deposits. Locally the deposits may be 12 to 20 feet thick.

Colluvial sediments are poorly sorted, unconsolidated erosional debris derived from residual soil, saprolite, unweathered rock, and old stream deposits, and transported downhill by sheet wash, creep, and frost action to accumulate on the lower slopes of hills or in depressions. Patchy sheet-wash deposits on the hillsides are the most widespread and typical of the colluvial sediments. Along the flanks of hills they unconformably overlie saprolite or hard rock, and locally the base of the colluvium is marked by a thin, discontinuous layer of angular fragments of quartz with which may be mixed a few waterworn quartz pebbles and rare blocks of unweathered rock. Isolated, older fluvial deposits are the source of the stream-worn pebbles, whereas the angular pieces of quartz and unweathered rock are derived locally. Overlying the layer of pebbles is a few inches to 40 feet of clayey sand which averages about 3 feet in thickness and is commonly unsorted but may be poorly and discontinuously bedded. Sheet-wash deposits lens out uphill or merge imperceptibly with the residual deposits on the divides.

Downhill they grade into and overlie colluvium in gullies, and they are truncated by or lap upon alluvial deposits in the valleys.

Old erosion gullies have been filled by colluvial deposits which range in thickness from 6 to 30 feet, consist of poorly sorted clay and sand, and commonly rest on saprolite or unweathered rock but locally lie on muck or gravel. Gully deposits are less abundant than sheet-wash sediments; the two form the bulk of the colluvium in the monazite belt.

Residual soil sampled in the drainage basin of Knob Creek in Cleveland County, N.C., contains nearly three times as much monazite per cubic yard as the saprolite from which it was derived:

Source rock	Monazite (lbs/cu yd)	
	Saprolite	Derived residual topsoil
Toluca quartz monzonite	0.2	0.4
Biotite gneiss	0.1	0.3
Biotite schist	0.04	0.16
Sillimanite schist	0.08	0.22

Residual topsoil and residual subsoil have about the same amount of monazite, 0.3 and 0.4 pound per cubic yard respectively in the Knob Creek area, but colluvial sediments in the same drainage basin contain about 10 times as much monazite as the residual soils and 30 times as much monazite as subjacent crystalline rocks. For seven samples of colluvial sediment the average tenor is 3.1 pounds of monazite per cubic yard, but the range in tenor among the samples is extreme: 0.2 pound to to 10.1 pounds of monazite per cubic yard. Colluvial deposits intersected by churn-drill hole K26 sunk by the U.S. Bureau of Mines on the upper western flank of an interstream area on the Bradshaw farm in the drainage basin of Knob Creek, Cleveland County, N.C., averaged 2.06 pounds of monazite to the cubic yard (field estimate) and ranged in tenor from 1.48 to 2.82 pounds per cubic yard (Griffith, R. F., written commun., 1951).

The average tenor of the residual soils is too low to allow them to be mined as eluvial placers, but some of the colluvial deposits contain about as much monazite as the alluvial sediments formerly mined at the heads of small streams. Compared with the average tenor of all stream sediments between the Savannah and Catawba Rivers, S.C.-N.C. (0.8 pound of monazite per cubic yard), the colluvial deposits in the drainage basin of Knob Creek are four times as rich. Elsewhere in the core of the monazite belt, similar concentrations of monazite have accumulated in the colluvium. However, the location of the deposits on the flanks of hills, the shallow average depth of the colluvium, and its patchy distribution combine to reduce its utility as a practical source for monazite. At best, some areas of colluvium on the lower hillsides might be stripped in conjunction with the mining of alluvial placers in the adjoining valleys, as was done in the past, but colluvial deposits alone are not minable. Their major role is that of intermediate host for monazite between bedrock and alluvium.

Alluvial placers in trunk drainage

The possible accumulation of monazite placers in the alluvium of trunk streams downstream from the western monazite belt appears to be remote. Trunk streams northwest of the Coastal Plain and north of the Catawba River, as the Pee Dee, Yadkin, Dan, and Roanoke Rivers, are improbable sources for monazite placers because only a small part of their drainage area crosses monazite-bearing terrain. The Catawba, Wateree, Broad, Saluda, and Congaree Rivers tap the largest source areas of monazite of any trunk streams leading from the belt. Southwest of the Saluda River and northwest of the Coastal Plain the Oconee River drains an area higher in monazite than those drained by the Savannah, Ocmulgee, Flint, and Chattahoochee Rivers.

Although the system of rivers joining southeast of Columbia, S.C., to form the Santee River includes the trunk streams most favorable for the possible accumulation of monazite because of large drainage basins in the monazite belt, the results of churn drilling in flood plains where the streams enter or emerge from the monazite belt are most unfavorable (table 17).

In the flood plain on the Catawba River, gravel makes up about 10 percent of the alluvium,but on the Broad River and North Tyger River gravel constitutes only about 3 percent of the sediment.

Table 17. Monazite in the alluvium of trunk streams at the margins of the western monazite belt

Stream	Position of flood plains with respect to the margins of the belt	Number of holes	Weighted average tenor in monazite 1/ (lbs/cu yd)
Catawba River, Burke County, N.C. 2/	West edge	3	0.14
Broad River, Cherokee County, S.C. 3/	East edge	8	.34
North Tyger River, Spartanburg County, S.C. 4/	East edge	16	.37

1/ Field estimates.

2/ Hansen and White, 1954, p. 27.

3/ Hansen and Theobald, 1955, p. 25.

4/ Hansen and Cuppels, 1955, p. 16.

The area drilled on the Catawba River is to the west of the core of the belt and cannot be expected to contain much more than a trace of monazite. However, the other areas should receive an appreciable influx of monazite. The site on the Broad River is downstream from 1,380 square miles of monazite-bearing country, and the flood plains on the North Tyger River are built of alluvium from 85 square miles of rocks that contain monazite. The low tenors in both areas can be attributed to two factors. The first is the dominance of fine-grained sediments in flood plains along the trunk streams, which is probably a constant characteristic of the streams between the belt and the Coastal Plain. The second factor is that too little monazite enters the trunk streams to cause an appreciable enrichment of the monazite-free suites of heavy minerals transported by the rivers from the area west of the belt. Reduction of the proportion of monazite in the suite of heavy minerals by adulteration from monazite-free suites would increase downstream toward the Coastal Plain.

Estimates ranging from 0.5 to 0.8 pound of monazite per cubic yard have been made for large volumes of alluvium in flood plains along major streams inside the western monazite belt. Drilling has shown that at or slightly downstream from the east edge of the belt the tenors are about half what they are inside the belt. The decline in value between the inferred tenors in the core of the belt and the indicated tenors at the east edge of the belt suggests that placer deposits are unlikely elsewhere on the major streams. A remote and unexamined possibility exists that near the fall line the proportion of gravel to other sediments increases, and that there would be greater amounts of black sand in the gravel deposits than there is in fine sand and silt farther upstream. Included with the black sand would be small percentages of monazite. This possibility could be examined readily by sampling gravel near Columbia, S.C.

Summary

None of the areas in the monazite belt northeast of the Catawba River, N.C., and southwest of the Savannah River, S.C., offers streams as favorable for placers as the core of the belt between those two rivers. Monazite is virtually absent from tributaries to the Yadkin and Dan Rivers in North Carolina and Virginia, and is sparse in streams entering the Flint and Chattahoochee Rivers in Georgia. The tributaries to the Oconee River, Ga., contain more monazite than those in the areas farther to the southwest, but they are not comparable in tenor, size, and proportion of coarse-grained sediment with the streams in the core of the belt in South Carolina and North Carolina.

Monazite-bearing bedrock that, whether weathered or fresh, generally contains less than 0.1 pound of monazite per cubic yard between the Savannah and Catawba Rivers is not an ore of monazite. In the same area the eluvial placers in residual soil contain 0.3 to 0.4 pound of monazite per cubic yard and thus are not suitable for mining. Eluvial placers in colluvial deposits are about 10 times as rich in monazite as the residual soil, but the patchy distribution and thin average depth of the colluvium would restrict their possible utilization to stripping concurrent with the mining of alluvium in adjacent valleys.

It is improbable that monazite placers have formed in the alluvium along trunk streams between the monazite belt and the Coastal Plain.

References cited

Crickmay, G. W., 1935, Kyanite in Talbot and Upson Counties: Georgia Geol. Survey Bull. 46, p. 32-36.

Hansen, L. A., and Cuppels, N. P., 1955, Monazite placer at the junction of the North Tyger River with the Middle Tyger River, Spartanburg County, South Carolina: U.S. Atomic Energy Comm. [Pub.] RME-3117, 23 p.

Hansen, L. A., and Theobald, P. K., Jr., 1955, Monazite placer on the Broad River and Thicketty Creek, Cherokee County, South Carolina: U.S. Atomic Energy Comm. [Pub.] RME-3126, 29 p.

Hansen, L. A., and White, A. M., 1954, Monazite placers on South Muddy Creek, McDowell County, and Silver Creek, Burke County, North Carolina: U.S. Atomic Energy Comm. [Pub.] RME-3115, 27 p.

Hewett, D. F., and Crickmay, G. W., 1937, The warm springs of Georgia, their geologic relations and origin--a summary report: U.S. Geol. Survey Water-Supply Paper 819, 40 p.

Mertie, J. B., Jr., 1953, Monazite deposits of the southeastern Atlantic States: U.S. Geol. Survey Circ. 237, 31 p.

References (continued)

Overstreet, W. C., 1967, The geologic occurrence of monazite: U.S. Geol. Survey Prof. Paper 530, 327 p.

Overstreet, W. C., Yates, R. G., and Griffitts, W. R., 1963, Heavy minerals in the saprolite of the crystalline rocks in the Shelby quadrangle, North Carolina: U.S. Geol. Survey Bull. 1162-F, 31 p.

Overstreet, W. C., White, A. M., Whitlow, J. W., Theobald, P. K., Jr., Caldwell, D. W., and Cuppels, N. P., 1968, Fluvial monazite deposits in the southeastern United States: U.S. Geol. Survey Prof. Paper 568, 85 p.

Parizek, E. J., 1953, A preliminary investigation of the geology of Clarke County, Georgia: Georgia Geol. Survey Bull. 60, pt. 2, p. 21-31.

_____________, 1955, Xenoliths in granodiorites of the east Georgia Piedmont: Georgia Acad. Sci. Bull., v. 13, no. 3, p. 85-89.

Stose, G. W., and Smith, R. W., 1939, Geologic map of Georgia: Georgia Div. Mines, Mining and Geology.