NORTH CAROLINA
DEPARTMENT OF CONSERVATION AND DEVELOPMENT
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DIVISION OF MINERAL RESOURCES
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Information Circular 19

TITANIUM DEPOSITS IN NORTH CAROLINA

BY

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PREPARED BY THE
BUREAU OF MINES
U.S. DEPARTMENT OF THE INTERIOR

RALEIGH
1964

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TITANIUM DEPOSITS IN NORTH CAROLINA

by

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ABSTRACT

Records of 110 mineral deposits were investigated for titanium and associated minerals in North Carolina. The deposits are of two types: (1) titaniferous hard rock deposits, and (2) heavy mineral placer deposits. The low mineral tenor or lack of data on the deposits eliminated their classification as "ore reserves"; however, records of drill holes and laboratory tests on samples showed that 7 deposits in the State were of sufficient magnitude to justify estimating their total content of ilmenite, rutile, zircon, and monazite.

The most extensively mined titanium mineral deposit in North Carolina is the Yadkin River deposit in Caldwell County, operated as an open pit by the Yadkin Valley Ilmenite Company, a subsidiary of Glidden Company, during the period 1942 - 1952, inclusive. The operation produced 215,400 tons of concentrate containing 51 percent TiO_2.

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Work on manuscript completed October 1961

INTRODUCTION

This investigation was made by the Federal Bureau of Mines to assemble and evaluate available data on titaniferous and heavy mineral deposits in North Carolina for the purpose of estimating and recording reserve data, together with describing the techniques and methods used in exploration, mining, and beneficiation. A resume of the geology is included for better understanding of the exploratory data.

This is one of a series of reports on titanium mineral deposits in the southeast, and is part of a Bureau of Mines survey of titanium resources in the United States.

Evaluation of the titaniferous deposits was limited by the lack of investigative data and lack of comparative processing costs for similar deposits. The evaluation of placer deposits was based on the inclusion of the four most desirable minerals: ilmenite, rutile, zircon, and monazite. Although garnet was plentiful, it was not included due to comparatively low value. Staurolite and sand and gravel were also excluded due to dependency on local market and low economic value. Much of the data used in this report was gathered from publications and monazite investigations.

Potential reserve estimates of the various deposits were not totaled, due to the wide range values per cubic yard and the lack of data on the most favorable areas. The total tonnage of the low grade titanium mineral deposits covered in this paper is only indicative of North Carolina's potential reserves.

ACKNOWLEDGEMENTS

The cooperation of the Division of Mineral Resources of North Carolina Department of Conservation and Develpoment is gratefully acknowledged, particularly, Dr. Jasper L. Stuckey , who gave personal assistance to the author.

PREMISES AND DEFINITIONS OF TERMS

Reserve estimates are usually based on certain premises adapted for the estimate. Therefore, the premises on which the estimate is based should be stated for proper interpretation of the results. In evaluating a mineral deposit, all minerals of appreciable economic value within the deposit should be considered. Therefore, in this evaluation of titanium minerals in the heavy mineral deposits in North Carolina, zircon and monazite are included with titanium minerals if they occur in the deposit. The other minerals were omitted due to recovery difficulties, limited market, or limited occurrence.

Hard Rock Deposit - Any deposit from which the mined ore requires crushing, preliminary to concentration, is designated as a hard rock deposit. Drilling and blasting is usually necessary before loading for transportation to a mill.

Placer Deposit - Material from this type of alluvial deposit requires no crushing before preliminary concentration. The deposit is usually composed of gravel, sand, silt, and packed clay or " hard pan " derived by the deposition of weathered rock carried by water. The deposition usually occurred when the stream action was retarded.

Sometimes wind action or slumping of weathered rock from rock cliff enters in the deposition.

Titaniferous - This term designates a hard rock deposit containing a combination of iron and titanium minerals, of which a chemical analysis shows more than 1.5 percent titanium dioxide. Although ilmenite and magnetite are the major titanium and iron minerals in the North Carolina deposits, rutile may be present.

Heavy Minerals - The occurrence in beach sands and flood plains of economically valuable minerals with a specific gravity greater than quartz established the term "heavy minerals" referring to a concentrate recovered by gravity separation. A more complete description of these minerals is in a section of this report titled, "Heavy Mineral Deposits", under "Mineralogy".

Black Sands - A term derived from the general color of heavy minerals. The term is used interchangeably with "heavy minerals".

Reserves - All titaniferous and heavy mineral deposits in North Carolina are of a potential nature and no commercial operations are active at the present time. Classification of reserves is limited to indicated and inferred with tabulations showing volumes in place and relative value.

Indicated Reserves - The term "indicated" refers to the degree of accuracy with which the volume and grade of the reserves are known. To fall within this classification, the reserves met the following requirements: Two or more sampled drill holes or shafts spaced less than 600 feet apart; geologic evidence not to exceed 1/2 mile (this was limited to 700 feet for some North Carolina deposits) from the

sampled drill holes or shafts, except in cases where geologic evidence justifies addition of 1/4 of a mile to join two indicated blocks; a field estimate of tenor of ilmenite, rutile, zircon, and monazite. The conditions for titaniferous deposits were not stated because investigative data was insufficient for estimating reserves.

Inferred Reserves - The volume of a heavy mineral placer deposit that lies adjacent to an indicated block was classed as inferred reserves if the area limitation and depth could be estimated by geologic inference. The extent of the area was limited to a maximum distance of 2 miles from the boundary of the indicated reserves. The mineral grade of the deposit was dependent on that of the adjoining indicated blocks. Sometimes inferred blocks were located between indicated blocks, each of which controls the grade to the midpoint of the inferred. A single sampled hole may be used to extend the inferred reserve using the same controlling action from the drill hole as was used from adjoining indicated blocks. The conditions for titaniferous deposits are not stated because investigative data is insufficient for estimating reserves.

Relative Value - The exact economic value of a deposit is based on many variable items which are subject to change. Therefore, the term "relative value" is used to show the comparative value of North Carolina titanium deposits, and is based on the market value of minerals found in a cubic yard of deposit without cost adjustments for royalty value, mining concentrating, etc.

Since ilmenite was the only mineral recovered from a titaniferous deposit in North Carolina in recent times, the relative value is calculated from ilmenite. Ilmenite, rutile, zircon, and monazite make up

about 50 percent of the heavy mineral fraction of the placer deposits; they are the principal sources of revenue, and all four should be included. The tenor of any one mineral would not give a correct evaluation of the deposit, as normal milling processes separate each one of these four minerals, if present, from the remaining heavy minerals of less ecomonic value. Therefore, a common value based on the sum of products of tenor and relative monetary value of each of the four named minerals is needed for proper comparison of evaluation of the deposits. Results are calculated from the formula:

Relative value = .012i + .040r + .025z + .150m

in which i = lbs. of ilmenite per cu. yd.

r = lbs. of rutile per cu. yd.

z = lbs. of zircon per cu. yd.

m = lbs of monazite per cu. yd.

GEOMORPHOLOGY

North Carolina is divided into three general geographic regions: the Coastal Plain, the Piedmont Province, and the Blue Ridge Province. The Coastal Plain extends from the coast to the fall line, a subregion of narrow valleys with distinct increase in the stream gradient (Fig. 1). The fall line extends across North Carolina from the Virginia boundary in the vicinity of Roanoke Rapids through Wilson to where the Pee Dee River enters South Carolina. The Piedmont Province extends from the fall line westward to the uplift of the Blue Ridge Mountains, beyond which is the Blue Ridge Province extending approximately to the Tennessee boundary. The uplift is a steeply sloping narrow region extending from the

Virginia boundary near the western limits of Surry County to the South Carolina boundary east of Lake Summit.

During Mississippian time, an older peneplain extending across the present Piedmont Province and Coastal Plain was subjected to a epeirogenic uplift; followed during Pennsylvanian time by development of an orogenic belt in the present Blue Ridge Province causing the peneplain to dip toward the Atlantic Ocean with submergence of the eastern Part. The present fall line marks the exposure of the older peneplain along the narrow area caused by a cycle of erosion of the elevated western portion and deposition over the submerged eastern portion. The Blue Ridge Province was formed by a faulted epeirogenic uplift during Permian time, and during that same time an orogenic belt developed over the present Coastal Plain. The present Piedmont Province was subjected to orogenic action during Triassic time, leaving Triassic deposits in basins partially bounded by faults.

Coastal Plain

In North Carolina, the Coastal Plain is about 100 miles wide, and is identified as the region between the continental shelf and the fall line. The topography ranges from the hilly region of the fall zone through a gently rolling peneplain to marsh land along the coast, and on out to a zone of sandy sea islands. Red sandy loam is noticeable in the fall zone, and gray to white sandy loam predominates in the general area of rolling country. Streams enter the Coastal Plain through comparatively narrow steeply sloped valleys which broaden and blend into

the general peneplain area as the sand hills disappear.

The Coastal Plain is underlain by poorly consolidated Tertiary and Cretaceous formations, which dip to the southeast at a steeper angle than the surface, causing, by erosion, exposure of the formations in decending order as the higher sand hills are approached from the coast. Exposures of a belt of Quaternary and Tertiary formations along the coast, range in width from 10 miles at the South Carolina line to 80 miles in the northern part of the Coastal Plain where the Yorktown of the Tertiary contacts Piedmont rocks without exposure of Cretaceous. However, Cretaceous formations are exposed in the southern part of the Coastal Plain of North Carolina, where exposure of the Tuscaloosa formation contacts the sand hills. Through wind and wave action, considerable concentration of heavy minerals has occurred along the coast.

Piedmont Province

A gentle undulating peneplain with more pronounced undulations in the vicinity of the rivers extending from the fall line to the southeastern slopes of the Blue Ridge Mountains represents the Piedmont Province, which is about 120 miles wide in North Carolina. The streams that drain the southeast slope of the Blue Ridge Mountains tend to start toward the northeast, then turn with general drainage pattern toward the southeast. However, tributaries in the vicinity of the sand hills assume a transverse course. The valleys are usually broad and shallow, but change as the fall line is approached, and become narrow and deep with steeper slopes.

The bed rocks exposed in the Piedmont are generally crystalline schist and gneiss with marble, quartzite, and conglomerate of probable Precambrian age with later intrusions of pegmatitic granite and diabase dikes. A belt of granite gneiss and mica schist occurs along the north west boundary of the Province. Sedimentary rocks of Triassic age are exposed in basins within two parallel troughs extending in a southwest to northeast direction.

The titaniferous deposits are generally found as irregular stringers or lens shaped masses in a belt extending from Reidsville to Mocksville and beyond, composed of Precambrian mica gneiss and schist contacting Paleozoic granite and gabbro.

Heavy minerals are usually found in flood plains of alluvium formed upstream from outcrops of resistant rocks such as granites. Less resistant hornblende and biotite gneiss usually underlie the flood plains. As water spread out over the flood plain and became less turbulent, the heavier mineral-bearing sands were deposited. However, this action was not as efficient for natural concentration as the constant wind and wave action along the coast.

Blue Ridge Province

The Blue Ridge Province, with a width of 30 to 50 miles, extends from the southeast slope of the Blue Ridge Mountains to the western boundary of North Carolina. It is an extremely rugged territory with elevations locally exceeding 6000 feet. Many of the stream valleys are narrow and winding. Although some drainage is toward the northeast into Virginia, the general drainage is toward the northwest. An outstanding

feature is that all of the water that falls on the southeastern slope of the Great Smoky Mountains, with elevations exceeding 6000 feet, flows into the Little Tennessee and French Broad rivers, and on to the Ohio and Mississippi rivers.

The exposed rocks in the Great Smoky Mountains are mostly Late Precambrian conglomerate, slate, and shale. In the middle and eastern part of the Blue Ridge Province, rock exposures are nearly all crystalline schist, gneiss, and igneous rocks with intrusions of pegmatitic gabbro and diabase dikes. The Brevard schist zone occurs parallel and near the eastern limits of the province.

The titaniferous deposits are usually found in a zone of Precambrian mica gneiss and schist adjacent to hornblende gneiss of Precambrian age. The zone extends along the western boundary of the state from Madison County to Ashe and Alleghany counties on the Virginia line. Titanium minerals are usually found in veins or dikes intruded through rocks of a schistose structure following the direction of their schistosity. The alluvial deposits of heavy minerals in the Blue Ridge Province are small and scattered. The ruggedness of the terrain is not conducive to the formation of extensive flood plains.

MINERALOGY

Types of Deposits

Titaniferous Rock Deposits

The titaniferous resources are basically hard rock deposits of ilmenite, magnetite, and minor amounts of rutile with intergrowths of magnetite-ilmenite and rutile-ilmenite associated with igneous and

metamorphic rocks. These rocks are granite, mica and hornlende-gneisses , and schists. The available analyses of North Carolina titaniferous deposits do not distinguish ilmenite from rutile as the source of the reported TiO_2. Although rutile may be present as indicated by an excess of TiO_2 over that needed to qualify as ilmenite, there is little doubt that ilmenite and magnetite are the principal mineral constituents. It is reasonable to assume that the maximum amount of ilmenite is present as indicated by chemical analysis. This was discussed in "Weight Volume Ratio" under " Premises and Definitions of Terms".

Heavy Mineral Sand Deposits

Heavy mineral deposits are found in both stream and beach placers. The usual suite of heavy minerals found in North Carolina deposits include: ilmenite, garnet, epidote, zircon, rutile, monazite, kyanite, magnetite, staurolite, and ferromagnesian minerals in the amphibole and the pyroxene groups. Other minerals often found are: xenotime, tourmaline, and leucoxene. Columbite occurs as an integrated part of ilmenite. A laboratory separation of heavy minerals includes some quartz due to abundance and integration with many of the heavy minerals. Sillimenite is sometimes associated with kyanite. Ilmenite, rutile, zircon, and monazite make up the suite of the most important economic minerals.

Ilmenite has a hardness of 5.5 - 6.0 and a specific gravity of 4.5 - 5.0. It is a ferrous titanite with theoretical 52.6 percent TiO_2. However, the percentage of FeO and TiO_2 vary. Ilmenite is primarily a source of the titanium dioxide used as a paint pigment.

Rutile is a titanium dioxide containing about 60 percent titanium, however, iron may be present. It has a hardness of 6.0 -6.5 and specific gravity of 4.2. Development of the chloride process for the production of titanium metal enhances the importance of rutile as a titanium ore.

Zircon is a zirconium silicate with a hardness of 7.5 and a specific gravity of 4.7. It is principally used as a foundry sand and as a refractory. Nuclear reactor construction has created a market for a specific grade of the metal. The oxide, zirconia, a high temperature material, has a market as a liner in the production of jet engines.

Monazite is primarily a rare earth phosphate mineral including thorium with a hardness of 5 - 5.5 and a specific gravity of 5.0 - 5.3 . Industry uses the mineral in the production of optics, gas mantles, alloys, and carbon arcs. A possible future use of thorium may be in the generation of nuclear power.

Magnetite is a common iron ore mineral with a hardness of 6 and specific gravity of 5.2. However, the commercial value of a magnetite deposit depends on volume , grade, and cost of removing undesirable materials in preparation for the manufacture of steel.

Xenotime and columbite have a specific gravity in excess of 4, but due to limited occurence have little commercial value as heavy minerals. Minerals with a specific gravity between 3 and 4 are epidote, kyanite, sillimanite, staurolite, and tourmaline. Quartz has a specific gravity of less than 3. Leucoxene is a name loosely applied to alteration products of high titanium minerals.

Specific Properties Related to Beneficiation

Separation of minerals associated with titanium minerals is based primarily on the differential of the following properties: specific gravity, magnetic susceptibility, conductivity, grain size, and amenability to flotation reagents.

The property of hardness of titaniferous minerals effects the grindability in crushing ore for classification. The difference in grain size and specific gravity is used for separation of mineral from gangue by classification. Results of flotation are affected by reaction of the mineral and gangue to conditioners and collectors (1 pp 124-135)[2] (18)

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2 / Underlined numbers in parentheses refer to items in the bibliography at end of this report. Pages cited refer to the item and not to this publication.

In the beneficiation of heavy minerals, difference of grain size and specific gravity is used in screening, gravity separation, and

classification. Electrostatic separators use the property of conductivity to separte the high conductors (ilmenite and rutile) from the low conductors (monazite, zircon, and others). Induced roll magnets make use of the differential of magnetic attractability to separate rutile (low) from ilmenite (high) and zircon (low) from monazite (high). Actual beneficiation involves many repetitive uses of the separating devices and other equipment within the circuits in order to get a cleaner product.

The comparable properties of the minerals is shown in table 1. Grain size is not listed in the table, as it is not an identifying property, and varies considerably. Reagents for flotation are omitted due to complexity and variance. The minerals are arranged in four vertical groups, depending on the magnitude of magnetic susceptibility. Horizontal grouping separates the conductors from the non-conductors.

RESERVES

Investigation of deposits containing titanium in North Carolina was limited to published and unpublished records which are not always complete.

The density of hard rock and alluvial deposits vary considerably. Titaniferous deposits may vary between 2-1/2 and 4 tons per cubic yard. The density of alluvium ranges from 1 ton to about 1.6 tons per cubic yard. If the sampled weight of a cubic yard or density of the minable material was available, it was used to convert "pounds or tons per cubic yard" to "percentages", or reverse, whichever was required. If sampled weights were not available, then the densities were calculated.

TABLE 1.- Properties of Minerals Related to Beneficiation and Separation

CONDUCTORS					
High magnetic[1]	Medium magnetic[1]	Weak magnetic[1]	Non-magnetic[1]	Conductivity in %/C° [2]	Specific gravity
Magnetite				99/50	5.2
Ilmenite				99/50	4.7
			Cassiterite	99/50	6.8-7.1
			Rutile	62/50	4.2
NON-CONDUCTORS					
	Monazite			9/50	5.0-5.3
			Zircon	6/50	4.7
		Epidote		4/50	3.4
	Staurolite			8/300	3.7
			Kyanite	4/400	3.6
			Quartz	1-3/400	2.7
		Tourmaline		1/500	3.0-3.2
	Xenotime				4.0-5.0
			Leucoxene		4.3^{+}_{-}
	Garnet				3.5-4.3

1/ Furnished by Carpco Research and Engineering, Inc.

2/ Represents the quantitative value of conductivity of the minerals based on probability of deflection in an electrostatic separator when the mineral is heated to the noted centigrade temperatures. See bibliography (2).

Methods of Sampling and Calculating Reserves

Investigations for heavy mineral deposits usually started with prospecting by panning, and if results were favorable, drilling followed. Quite often the preliminary investigation was done with a prospect drill hole. Drilling usually consisted of rows of holes across the width of the deposit.

Where sufficient data were available for estimation of volume of material, maps were prepared showing some physical features such as roads, the location of drill holes, course of streams, and outlines of deposit, such as the limits of the flood plain or minable limits. The minable area was divided into blocks of indicated and inferred reserves.

The volume of material in each block was calculated by measuring the area with a planimeter and multiplying this by the weighted average depth. This depth was calculated from a cross-section formed by a row of holes across the deposit near the mid-point of the block. The depth of inferred blocks was determined from that of the adjoining indicated blocks unless more definite data were available. The mineral content was converted to pounds per cubic yard. A weighted average was calculated for each row of holes for each mineral, and then applied to the volumes of corresponding blocks.

If the measured density of alluvium in a placer deposit is not available, then the most common density of 2700 pounds per cubic yard or 1.35 tons per cubic yard of alluvium is used. This is adjusted for heavy mineral content using the equation:

$$\text{Lbs. of alluvium per cu. yd.} = \frac{2700}{1.00 - \% \text{ of heavy minerals } \left(1-\frac{2.8}{4.6}\right)}$$

or

$$\text{Lbs. of alluvium per cu. yd.} = \frac{2700}{1.00 - .39 \times \% \text{ of heavy minerals}}$$

In which

2.8 = approximate specific gravity of alluvium

4.6 = approximate specific gravity of heavy minerals.

The hard rock deposits in North Carolina are principally composed of ilmenite and magnetite, and possible small amounts of rutile with granite gneiss, schist, etc. as the gangue materials. Analyses are usually stated in percentage of TiO_2 and Fe. It was assumed that all the TiO_2 and Fe that occurred in the ratio of 10 parts TiO_2 to 7 parts Fe was in the form of ilmenite. Any excess TiO_2 was considered as rutile, and any excess Fe was considered as magnetite; however, an excess of TiO_2 was very unlikely. The deposits usually contained less than 1 part rutile to 10 parts ilmenite, and any misrepresentation of ilmenite for rutile and magnetite would have little appreciable effect on the above assumption, since an accuracy of 99.68 percent would still be maintained under the 1 to 10 ratio as shown by molecular weights.

Molecular weight of Fe_3O_4 (231.55) + 3 TiO_2 (239.70) = 471.25

Molecular weight of 3 Fe TiO_3 = 455.25

$$\frac{455.25 \times 11}{455.25 \times 10 + 471.25} = 99.68\%$$

Insufficient data obstructed the calculation of reserves of hard rock deposit. However, the tonnage of ilmenite reported recovered from

TABLE 2.- Composition of Titaniferous and Heavy Mineral Deposits in North Carolina

Note: A dash represents lack of data

No.	Location	Percent Fe	Percent TiO_2	Lbs. of concentrate per cu. yd.	Percent mineral composition of concentrate: Ilmenite	Rutile	Zircon	Monazite
1-R	Shooting Creek	-	.44	30.5	-	-	-	-
2-T	Waldroop	20.64	3.20	-	-	-	-	-
3-T	Kilpatrick	54.24	17.60	-	-	-	-	-
4-G	Cullowhee	-	-	-	15.0	-	-	-
5-G	Thorpe	-	-	-	12.5	-	-	1.5
6-G	Tuckasegee	-	-	-	6.0	-	1.0	-
7-G	West Fork No. 1	-	-	-	3.5	-	1.0	6.0
8-G	West Fork No. 2	-	-	-	6.0	-	1.0	-
9-G	Rosman	-	-	-	28.0	2.5	2.0	0.5
10-G	Brevard	-	-	-	30.0	1.0	1.0	-
11-G	Lake Summit	-	-	-	12.0	12.0	3.0	-
12-G	Hendersonville	-	-	-	42.0	-	3.0	-
13-G	Cane Creek	-	-	-	35.0	-	2.0	0.5
14-G	Wilson Road	-	-	-	6.0	-	8.0	2.5
15-G	Swannanoa River	-	-	-	14.0	1.0	-	0.5
16-T	Spring Creek	62.16	7.44	-	-	-	-	-
17-G	Ivy Creek No. 1	-	-	-	58.0	-	1.0	-
18-T	Ivy Creek No. 2	32.26	37.88	-	-	-	-	-
19-T	Paint Fork	(TiO_2 in large quantities)						
20-T	Possum Trot Creek	39.00	2.56	-	-	-	-	-
21-G	Bald Creek	-	-	-	20.0	-	-	-
22-G	Cane River	-	-	-	14.0	-	-	-
23-T	Ramsaytown	-	-	-	-	-	-	-
24-T	Mine Fork	39.42	11.90	-	-	-	-	-
25-T	Greasy Creek	54.48	4.96	-	-	-	-	-

TABLE 2.- Composition of Titaniferous and Heavy Mineral Deposits in North Carolina (continued)

Note: A dash represents lack of data

No	Location	Percent		Lbs. of concentrate per cu. yd.	Percent mineral composition of concentrate			
		Fe	TiO_2		Ilmenite	Rutile	Zircon	Monazite
49-P	Henderson Branch	-	-	20.3	-	-	-	31.0
50-P	Chunk Creek	-	-	40.5	-	-	-	57.0
51-D	Cathey's Creek	-	-	8.7	48.0	-	7.0	4.0
52	Robinson Creek	-	-	10.0	-	-	-	15.0
53-D	Cane Creek	-	-	14.4	42.0	-	7.0	3.0
54-P	Duncans Creek	-	-	9.9	-	-	-	60.0
55-R	Sandy Run	-	-	24.1	34.3	5.4	0.5	6.8
56-P	Webb Creek	-	-	24.4	-	-	-	67.0
57-P	Second Broad River	-	-	7.4	-	-	-	68.0
58-P	Monazite Branch	-	-	18.7	-	-	-	68.0
59-P	Sandy Run	-	-	14.3	-	-	-	62.0
60-P	West Sandy Run	-	-	8.0	-	-	-	56.0
61-P	Beaver Dam Creek	-	-	18.2	-	-	-	49.0
62-P	Little Hickory Creek	-	-	8.7	-	-	-	45.0
63-P	Hickory Creek	-	-	5.2	-	-	-	58.0
64-P	Brush Creek S	-	-	48.3	-	-	-	22.0
65-P	Brush Creek N	-	-	15.0	-	-	-	24.0
66-P	Grassy Creek	-	-	14.6	-	-	-	65.0
67-P	Long Branch	-	-	3.1	-	-	-	58.0
68-P	West Buffalo Creek S	-	-	3.7	-	-	-	60.0
69-P	West Buffalo Creek N	-	-	8.7	-	-	-	33.0
70-R	Buffalo Creek	-	-	38.9	18.2	2.6	0.5	3.2
70-P	Buffalo Creek	-	-	9.9	-	-	-	61.0
71-P	Maple and Knob Creeks	-	-	48.4	-	-	-	55.0
72-P	Crooked Run S	-	-	15.9	-	-	-	66.0
73-R	First Broad River and tributaries	-	-	17.4	32.0	2.0	3.0	4.5

TABLE 2.- Composition of Titaniferous and Heavy Mineral Deposits in North Carolina (continued)

Note: A dash represents lack of data

No.	Location	Percent		Lbs. of concentrate per cu. yd.	Percent mineral composition of concentrate			
		Fe	TiO_2		Ilmenite	Rutile	Zircon	Monazite
74-P	Crooked Run N	-	-	8.8	-	-	-	37.0
75-P	Bald Knob Creek	-	-	15.5	-	-	-	30.0
76-R	Knob Creek	-	-	18.3	24.5	-	1.1	9.1
76-P	Knob Creek	-	-	8.7	-	-	-	56.0
77-P	East Knob Creek	-	-	6.1	-	-	-	50.0
78-T	Indian Creek	56.95	2.40	-	-	-	-	-
79-P	Camp Creek	-	-	17.0	-	-	-	42.0
80-P	Rock Creek	-	-	16.3	-	-	-	43.0
81-D	Halls Creek	-	-	30.0	42.0	-	4.0	3.0
82-R	Silver Creek	-	-	12.12	32.0	2.0	6.0	6.5
82-P	Silver Creek	-	-	8.5	-	-	-	47.0
83-D	Catawba River	-	-	14.9	47.0	2.0	7.0	1.0
84-T	Forney Mine	67.92	1.60	-	-	-	-	-
85-G	Hagan Creek	-	-	-	30.0	1.0	-	2.5
86-G	Duck Creek	-	-	-	16.0	-	3.0	3.0
87-P	Third Creek	-	-	20.7	-	-	-	13.0
88-T	Bear Creek	60.00	10.32	-	-	-	-	-
89-T	Dutchman's Creek	52.80	8.00	-	-	-	-	-
90-T	Charles	59.03	11.95	-	-	-	-	-
91-T	Cook	56.21	13.28	-	-	-	-	-
92-T	Tuscarora Mine	53.84	13.59	-	-	-	-	-
93-T	Trueblood	-	-	-	-	-	-	-
94-T	Lewis	57.32	12.27	-	-	-	-	-
95-T	Shaw Mine	54.17	14.46	-	-	-	-	-
96-T	Dannemora Mine	48.41	13.74	-	-	-	-	-
97-T	Hopkins	55.61	13.92	-	-	-	-	-

TABLE 2.- Composition of Titaniferous and Heavy Mineral Deposits in North Carolina (continued)

Note: A dash represents lack of data

No.	Location	Percent		Lbs. of concentrate per cu. yd.	Percent mineral composition of concentrate			
		Fe	TiO_2		Ilmenite	Rutile	Zircon	Monazite
98-T	Apple	32.25	1.60	-	-	-	-	-
99-G	Nicks Creek	-	-	-	58.0	1.0	5.0	7.0
100-G	Little River	-	-	-	55.0	3.0	4.0	3.0
101-G	Cumberland Sand and gravel	-	-	-	46.0	5.0	10.0	4.0
102	Allied-Kennecott Titanium Corp.	-	-	-	-	-	-	-
103-D	New Hanover	-	-	81.0	-	-	-	-
104-S	Topsail	-	-	-	-	-	-	-
105-D	Morehead	-	-	24.0	-	-	-	-
106-D	No. 1 Township	-	-	102.6	-	-	-	-
107-D	Richland S	-	-	108.0	-	-	-	-
108-D	Richland N	-	-	56.7	-	-	-	-
109	Chowan	-	-	-	-	-	-	-
110-D	Perquimans	-	-	81.0	-	-	-	-
111	Albermarle Sound	-	-	-	-	-	-	-

the Yadkin River deposit was checked against the volume of material removed by assuming that any Fe in excess to the theoretical amount in ilmenite would be in the form of magnetite. The density of the deposit was calculated from the following equation:

$$\frac{\%\ \text{ilmenite}}{4} + \frac{\%\ \text{magnetite}}{4.4} + \frac{1.00 - (\%\ \text{ilmenite} + \%\ \text{magnetite})}{2.3} = \frac{1.00}{\text{ton/cu.yd.}}$$

By using the analyzed percentages of TiO_2 and Fe, this equation was converted to:

$$\frac{\%\ TiO_2}{.526X4} + \frac{\%\ Fe}{.724X4.4} - \frac{\%TiO_2\ X\ .368}{.526X.724X4.4} + \frac{1}{2/3} - \frac{\%\ TiO_2}{.526X2.3} - \frac{\%\ Fe}{.724X2.3} +$$

$$\frac{\%\ TiO_2 X.368}{.526X.724X2.3} = \frac{1}{\text{tons per cu. yd.}}$$

$$\text{or tons per cu.yd.} = \frac{1}{.435 - .151\ X\ \%\ TiO_2 - .286\ X\ \%\ Fe}$$

in which:

52.6% = TiO_2 in ilmenite ($TiFeO_3$)

36.8% = Iron in ilmenite

72.4% = Iron in magnetite (Fe_3O_3)

4.0 tons = Weight of 1 cubic yard of ilmenite

4.4 tons = Weight of 1 cubic yard of magnetite

2.3 tons = Weight of 1 cubic yard of average rock (granite, gneiss, schist, etc.)

Table 2 lists all deposits containing a titanium mineral with the analysis of the most important minerals. The percent of TiO_2 and Fe is shown for the titaniferous deposits, and for the heavy mineral deposits the total pounds of heavy mineral per cubic yard is shown with the percent of ilmenite, rutile, zircon, and monazite in the heavy mineral concentrate. Parts of the above data was not always

available, and had to be omitted.

Table 3 includes tonnage and relative value of each of the four commercial minerals of those deposits of which there were sufficient data for calculations. The total relative value is also stated which can be compared with an estimated placer mining costs of 40 cents per cubic yard, excluding interest, depletion, taxes, and royalties. This was limited to the heavy mineral deposits as sufficient investigative data were lacking on the titaniferous deposits. Seven deposits were entered with a breakdown of indicated and inferred reserves.

Locations and Descriptions of Titaniferous and Heavy Mineral Prospects and Deposits

One hundred and ten prospects and deposits are briefly described on the following pages, with reference as to source of data. Each of the prospects or deposits has a code identity composed of a sequence number and a letter suffix. The suffix "T" denotes a titaniferous deposit; "G" denotes Bureau of Mines grab samples; "R" denotes calculated reserves obtained from published data; "D" denotes data obtained from drill hole records; "P" denotes prospect data from a U.S.G.S. publication; and "S" denotes North Carolina Division of Mineral Resources publication as a source of data. Locations of all occurrences are shown on figure 1, and other data are given in tables 2 or 3.

1-R - Shooting Creek (4)

The Shooting Creek placer deposit is in the Blue Ridge Province

TABLE 3.- Evaluation of Reserves of Heavy Minerals in North Carolina

Note: Data from other reports and publications

No.	Location	Class[1]	Pounds per cubic yard: Concentrate	Ilmenite	Rutile	Zircon	Monazite	Relative value per cubic yard: Ilmenite	Rutile	Zircon	Monazite	Total	Tons of minerals: Ilmenite	Rutile	Zircon	Monazite	Area, thousand sq. yds.	Volume, thousand cu. yds.	Total relative value
1-R	Shooting Creek	F	30.5		12(TiO_2)							0.37		68,812(TiO_2)			4,138	11,225	$4,153,000
46-R	South Muddy Creek	D	9.6	2.21		0.77	0.64	.027		.019	.096	0.14[2]	5,290		1,840	1,530	798	4,788	479,000[2]
		F	8.1	1.86		0.64	0.60	.022		.016	.090	0.13[2]	13,000		4,500	4,200	2,300	14,000	1,820,000[2]
55-R	Sandy Run	D	24.1	8.28	1.30	0.12	1.63	.099	.052	.003	.245	0.34	5,600	880	80	1,100	355	1,353	433,000
		F											7,900	1,200	100	1,500	500	1,900	646,000
70-R	Buffalo Creek	D	38.9	7.09	1.01	0.19	1.25	.085	.040	.005	.188	0.32	7,730	1,100	200	1,370	584	2,180	697,000
73-R	First Broad River and tributaries	D	17.4	5.52	0.35	0.53	0.79	.066	.014	.013	.118	0.21	50,410	3,200	4,850	7,220	2,561	18,262	3,900,000
	First Broad River	D	20.3	6.28	0.41	0.71	0.85	.075	.016	.017	.128	0.24	30,400	1,980	3,420	4,110	1,263	9,681	2,324,000
	Hinton Creek	D	10.9	3.80	0.49	0.38	0.72	.046	.020	.009	.108	0.18	7,120	910	710	1,350	592	3,750	675,000
	Duncans Creek	D	23.9	5.73	-	-	0.74	.069	-	-	.111	0.18	4,720	-	-	610	176	1,648	297,000
	Wards Creek	D	12.8	5.13	0.19	0.45	0.72	.062	.008	.011	.108	0.19	8,160	300	710	1,140	530	3,183	604,000
76-R	Knob Creek	D	18.3	4.49	-	0.20	1.67	.054	-	.005	.251	0.31	7,470	-	380	2,780	541	3,331	1,033,000
		F											4,300		200	1,600	310	1,900	589,000
82-R	Silver Creek	D	12.7	4.08	0.26	0.76	0.83	.049	.010	.019	.125	0.20[3]	4,480	286	830	910	330	2,198	440,000[3]
		F	12.0	3.84	0.24	0.72	0.79	.046	.010	.018	.119	0.19[3]	22,160	1,380	4,150	4,560	1,732	11,545	2,194,000[3]

1/ D = Indicated F = Inferred

2/ Add .04 per cubic yard for gold content.

3/ Add .03 per cubic yard for gold content.

about 6 miles east of Haysville, Clay County. U. S. Highway 64 and Shooting Creek pass through the deposit, which extends over about 850 acres to 1200 acres; some of which is flooded by the Chatuga Reservoir. An unpublished report by Ford, Bacon, and Davis estimates 11 million cubic yards of recoverable material, containing 172,000 tons of concentrate, of which 40 percent is recoverable TiO_2, based on the weighted averages of contained TiO_2 in 28 analyzed samples of concentrate.

The underlying rock is composed of gneiss, mica schist, and pegmatite with intrusions of quartz veins. Rutile and ilmenite occur abundantly in the vicinity of the mica schist belts. In the unweathered rock, the titaniferous minerals appear to be more intimately associated with the quartz stringers than in the mica schists.

2-T - Waldroop (5, p 91)(6, p 194)(7, p 225)

A titaniferous occurence in Macon County about 4 miles southwest of Franklin was reported at the Alex Waldroop place. Analysis showed 3.20 percent TiO_2. "The ore was very fine-grained in a chloritic gangue, and in places slightly garnetiferous".

3-T - Kilpatrick (5, p 91)(6, p 192)(7, p 226)

A titaniferous occurrence under the name Felix Kilpatrick in Macon County, 5 miles southeast of Franklin, was reported to contain 17.6 percent TiO_2. It was described as a "heavy surface float a massive lustrous magnetite" with quartz and chlorite gangue; "the ore was traceable for several hundred yards".

4-G - Cullowhee (8, p 63)

A sample was obtained from a stream bar in the Tuckaseigee River

near Cullowhee in Jackson County along State Highway 107. The ilmenite content of the concentrate was about 15 percent.

5-G - Thorpe (8, p 63)

Two samples were taken from stream gravel in the vicinity of the penstock from Lake Thorpe in Jackson County near State Highway 107 . The average ilmenite content was about 12.5 percent of the concentrate.

6-G - Tuckaseigee (8, p 63)

A sample obtained from a stream bar in the Tuckaseigee River near Cullowhee along State Highway 107 in Jackson County showed a 6 percent ilmenite content in the concentrate.

7-G - West Fork No. 1 (8, p 65)

Two samples which had an average ilmenite content of 3.5 percent of the concentrate were obtained from decomposed pegmatite two miles north of U.S. Highway 64 near West Fork of the French Broad River in Transylvania County.

8-G - West Fork No. 2 (8, p 65)

A sample was obtained from the stream bottom of West Fork near the crossing of U.S. Highway 64 in Transylvania County. The concentrate showed 6 percent ilmenite.

9-G - Rosman (8, p 65)

Just below Rosman on the French Broad River in Transylvania

County, a sample was taken from the bank silt showing 50 percent ilmenite in the concentrate; another one from a gravel bar showed only 5 percent ilmenite, averaging 28 percent.

10-G Brevard (8, p 165)

A sample obtained from a channel in the river bank where State Highway 276 crosses the Davidson River in Transylvania County showed 30 percent ilmenite in the concentrate.

11-G - Lake Summit (8, p 63)

A pegmatite dike 3/4 of a mile northeast of U.S. Highway 25, crossing over Lake Summit in Henderson County was sampled. The concentrate of the sample contained 24 percent ilmenite and rutile.

12-G - Hendersonville (8, p 63)

A sample was taken east of Hendersonville in Henderson County at the crossing of U.S. Highway 64 over Mud Creek. The concentrate contained 42 percent ilmenite.

13-G - Cane Creek (8, p 62)

Cane Creek was sampled 1.2 miles south of U.S. Highway 74 in Buncombe County. The ilmenite content of the concentrate was 35 percent.

14-G - Wilson Road (8, p 62)

A sample was obtained at the intersection of Wilson Road and

a tributary of Cane Creek in Buncombe County. Only 6 percent ilmenite showed in the sample.

15-G - Swannanoa River (8, p 62)

Five samples were taken at a sand plant near Moore Central Hospital east of Asheville, Buncombe County. The samples were taken from various phases of the operation, and averaged 15 percent ilmenite and rutile in the concentrate.

16-T - Spring Creek (5, p 92)(6, p 190)(7, p 224)

"A vein of ore 5 feet to 6 feet wide" at the headwaters of Spring Creek in Madison County was reported to contain 7.44 percent TiO_2. It is a titaniferous deposit.

17-G - Ivy Creek No. 1 (8, p 64)

Stream gravel on Ivy Creek 2.3 miles northeast of U. S. Highway 70 in Madison County showed a concentrate containing 58 percent ilmenite.

18-T - Ivy Creek No. 2 (5, p 92) (6, p 225)(7, p 224)

The headwater of Ivy Creek near U.S. Highway 19 in Madison County is "one of the most notable occurrences of titaniferous ore in the state". The ore was reported to contain 37.88 percent TiO_2.

19-T - Paint Fork (5, p 92)(6, p 225)(7, p 224)

In Madison County " on the waters of Paint Fork half a mile above its mouth---non-magnetic high lustrous float ore contains TiO_2 in large quantities".

20-T - Possum Trot Creek (5, p 93)(6, p 186)(7, p 223)

A float ore at the head of Possum Trot Creek 9 miles west of Burnsville in Yancey County was reported to contain 2.56 percent TiO_2.

21-G - Bald Creek (8, p 65)

A sample obtained from the mouth of Bald Creek at location 21-G in Yancey County showed a concentrate containing 20 percent ilmenite.

22-G - Cane River (8, p 65)

Stream gravel was sampled near the bank of Cane River 500 feet up stream from U.S. Highway 19 in Yancey County. The concentrate showed 14 percent ilmenite.

23-T - Ramseytown (9, p 8)

A titaniferous occurrence was reported at location 23-T, 5 miles northwest of Burnsville, near Ramseytown in Yancey County.

24-T - Mine Fork (5, p 93)(6, p 228)(7, p 223)(9, p 8)

A sample was taken in Yancey County from a deposit "6 miles north of Burnsville on the south side of Mine Fork, a half mile above its mouth---a vertical bed of ore 6 to 10 feet across". The ore was reported to contain 11.90 percent TiO_2 .

25-T - Greasy Creek (5, p 92)(6, p 181)(7, p 220)

A titaniferous ore occurs on a spur of Iron Mountain above

Jenkins Mine, about 350 feet above Greasy Creek and 2-1/2 miles above the mouth of the creek in Mitchell County. "The ore is said to be in a vein 5-1/2 feet thick", and reported to contain 4.96 percent TiO_2.

26-T - Little Rock Creek (5, p 92)(6, p 183)(7, p 221)

"An ore lens about 3 feet across" is located in Mitchell County "on the north side of Little Rock Creek, half a mile from its junction with Big Rock Creek---". The TiO_2 content was reported to be 4.48 percent.

27-T - Wadkins Branch (5, p 92)(6, p 184)(7, p 221)

A titanferous deposit occurs at the headwaters of Wadkins Branch in Mitchell County, about 2 miles northwest of Bakersville. The reported content of TiO_2 was 4.56 percent (table 2).

28-G - Crabtree Creek (8, p 64)

Two samples were obtained along Crabtree Creek west of Spruce Pine in Mitchell County; one was from a gravel bar below U.S. Highway 19-E, and the other was from stream bottom gravels. The average titanium mineral content was 46 percent of the concentrate.

29-G - Penland (8, p 64)

Two gravel bars in North Toe River were sampled near Penland in Mitchell County. Fifty-four percent was the average content of ilmenite and rutile in the concentrate.

30-T - Buckridge (9, p 8)

A titaniferous occurrence was reported 2 miles northwest of Spruce Pine in the vicinity of Buck Ridge in Mitchell County.

31-T - Ingalls (9, p 8)

A titaniferous occurrence was reported near Ingalls, Avery County, 3 miles northeast of Spruce Pine.

32-G - Spear (8, p 61)

Stream gravel was sampled fron Henson Creek, 3/4 mile above Spear in Avery County. Results showed 36 percent titanium minerals in the concentrate.

33-G - Plumtree (8, p 61)

Plumtree Creek gravel was sampled near U.S. Highway 19-E in Avery County, and found to contain 21 percent titanium minerals in the concentrate.

34-T - Senia (7, p 218)

A sample taken at the mouth of Roaring Creek near Senia in Avery County was described as: "The ore is a fine-grained glistening variety like titaniferous ores elsewhere".

35-T - Avery Place (7, p 219)

Avery Place, a titaniferous deposit near the head of Old Cabin Branch, is in Avery County. Two analyses were reported which average 5.80 percent TiO_2. The ore was reported as occurring "in thin irregular

seams and lenses from 2 inches to 2 feet in thickness".

36-T - Grassy Bald (7, p 219)

Grassy Bald on Roan Mountain in Avery County was described as: "All of the magnetite appeared to be in the form of irregular constituents of a pegmatite". It was reported that a test made by the U. S. Geological Survey Laboratory showed 2 percent TiO_2.

37-T - Pennington (5, p 84)(6, p 218)(7, p 216)

The openings near Wallens Creek in Ashe County north of Sturgill are described as "an 8-foot vein of a fine-grained, compact, steel gray granular magnetite". The three analyses which were reported averaged 7.8 percent TiO_2.

38-T - Bauguess (5, p 84)(6, p 218)(7, p 215)

Bauguess is on a hill between Wallens Creek and Little Helton Creek near Sturgill, Ashe County. It is described as "5 feet of ore having a reddish streak in a gangue of epidote,feldspar, and quartz". The average of the two reported analyses showed 4.8 percent TiO_2.

39-T - McCarter (5, p 82)(6, p 218)(7, p 215)

The McCarter place is near Little Helton Creek in Ashe County. An eastern opening was described as 3 feet of ore "in hornblende, partially altered to asbestos". "The western opening---not more than one foot wide". Three analyses were reported which averaged 6.9 percent TiO_2.

40-T - Young (5, p 82)(6, p 219)(7, p 210)

The Young Place, on a hill above Shippey Branch in Ashe County, is described as an "outcrop of magnetite---covering a width of 25 feet". The reported two analyses averaged 6.87 percent TiO_2.

41-G - New River (8, p 61)

A stream bar in New River in the vicinity of the Virginia boundary with Alleghany County in North Carolina was sampled. The concentrate showed 55 percent ilmenite.

42-T - Carrico (5, p 84)(6, p 216)(7, p 217)

The Carrico pits were reported to be along the Virginia-North Carolina boundary about 3 miles west of the east line of Alleghany County. The analysis reported 4.86 percent TiO_2.

43-T - Yadkin Valley (10, p 26, 27)(11)

The Yadkin Valley deposit is at Richland in Caldwell County along the east bank of the Yadkin River, about 2 miles east of U.S. Highway 321, and 3 miles southeast of Baily Camp. The total distance of road from Baily Camp to the mine is about 7 miles.

The ore consists of lenses of ilmenite in sericitic talc between a footwall of gneiss and a hanging wall of schist, varying in thickneas from 20 to 50 feet, with an average dip of about 60 degrees. The crude ore was reported to contain 41.4 percent TiO_2.

The Yadkin Valley Mica and Ilmenite Company, formerly the Yadkin Valley Ilmenite Company, a subsidiary of Glidden Company,

operated a mine and mill on the property between the years 1942 and 1952, removing about 75,000 cubic yards of ore from a pit about 1200 feet long, from which 215,400 tons of concentrate containing an average of 51 percent TiO_2 were recovered.

The ore was drilled and blasted, and loaded into trucks with a one-fourth yard gasoline-powered shovel for haulage to the mill, where it was dumped into a bin above the crusher. After crushing, the ore was processed by classifiers, screens, and cones, followed by flotation to produce the concentrate.

After the relatively soft ore had been mined from the upper part of the deposit, operations ceased due to increased costs of mining and concentration of the hard underlying ore.

Although all machinery has been removed from the mill, the buildings are standing, but are in need of repair.

44-T - Warrior (5, p 85)(6, p 119)(7, p 228)

A titaniferous deposit near Warrior in Caldwell County was reported as "an outcrop of compact fine-grained magnetite in a gangue of green hornblende". The reported analysis showed a TiO_2 content of 2.40 percent.

45-G - Armstrong Creek (8, p 64)

A gravel bar in Armstrong Creek was sampled east of U.S. Highway 221 in McDowell County. The concentrate contained about 22 percent titanium minerals.

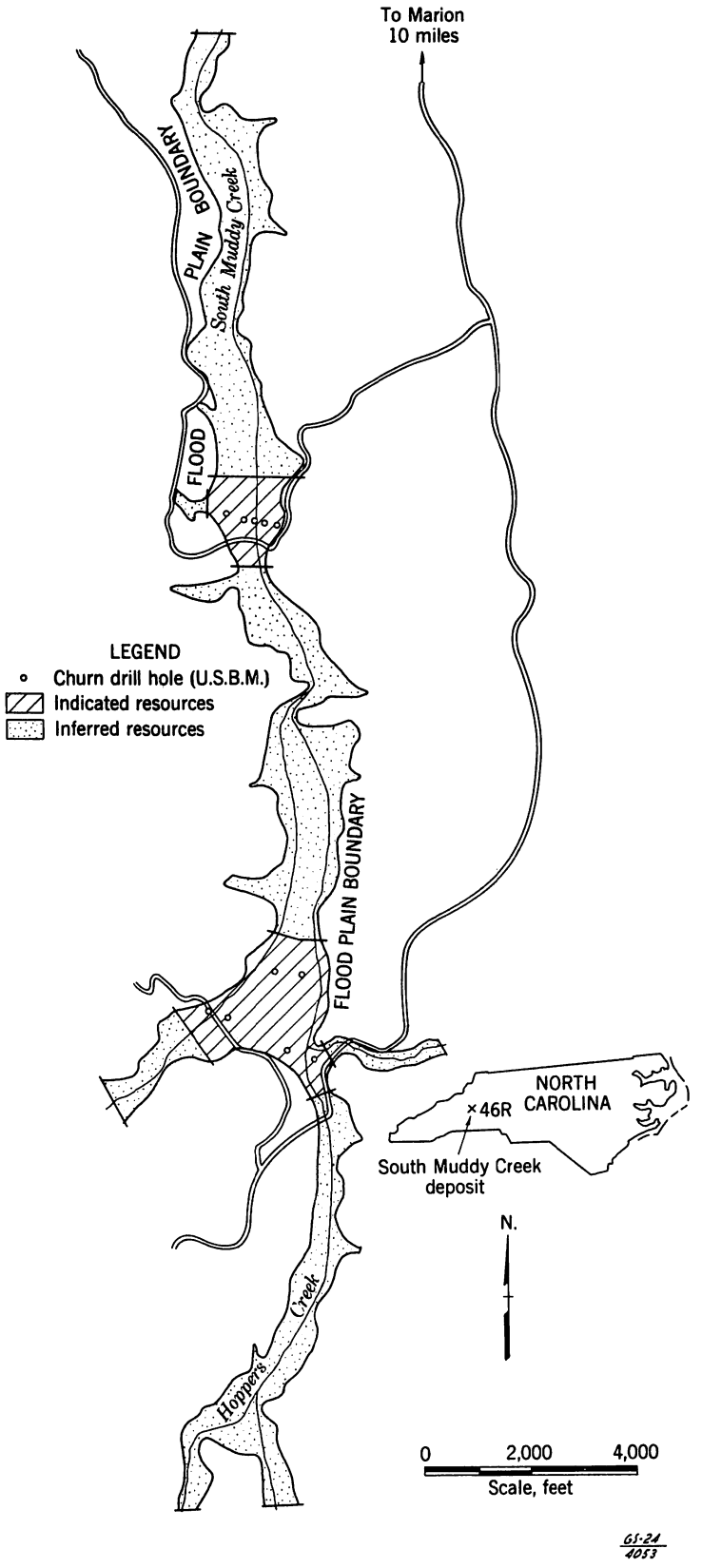

Figure 2.- South Muddy Creek Deposit, McDowell County, North Carolina

46-R - South Muddy Creek (12)

This placer deposit is in McDowell County in the flood plains of South Muddy Creek, and a tributary of Hoppers Creek about 9 miles east of Marion (Fig. 2). It is south of Interstate Highway 40, and extends up-stream to the south for a distance of 5 miles. Eleven churn drill holes in two groups controlled estimates for 460 acres of the deposit averaging 18 feet deep. Geologic evidence limited the indicated area to extend not more than 700 feet from a drill hole, and covering about 165 acres. The drainage basin is underlain by complex rocks consisting of gneiss, granite, schist, and pegmatites. The most prevalent heavy minerals included in the concentrate are ilmenite, quartz, epidote, magnetite, zircon and monazite. Twenty-three percent of the concentrate is ilmenite. Gold was reported to occur in the concentrate.

47-P - Alexander Creek (13, p 8)

This placer prospect is in McDowell County on Alexander Creek, a tributary to Muddy Creek, about 8 miles southeast of Marion. A heavy mineral content of 1.1 percent was reported.

48-G - Lake Lure (8, p 65)

A sample obtained from a sand recovery operation on Broad River near the head of Lake Lure in Rutherford County reported ten percent ilmenite in the concentrate.

49-P - Henderson Branch (13, p 8)

Samples taken from Henderson Branch about 2 miles east of Rutherfordton in Rutherford County showed a heavy mineral content of 0.8 percent.

50-P - Chunk Creek (13, p 8)

A heavy mineral content of 1.5 percent was reported at a placer deposit on Chunk Creek in Rutherford County about 2-1/2 miles east of Rutherfordton.

51-D - Cathey's Creek

Four holes were drilled along Cathey's Creek, a tributary of Second Broad River, about 2 miles northeast of Rutherfordton, Rutherford County. One hole was drilled at the mouth of the creek, and another about 400 feet above the mouth. The other two were drilled further up-stream; one at the mouth of a branch, and the other was 500 feet farther up stream. The holes ranged in depth from 21 feet to 26 feet, with an average thickness of 21 feet. Samples from the holes averaged 0.3 percent heavy minerals containing about 48 percent ilmenite. Occurrence of gold was reported.

Two of the holes started in top soil, and cut sand and gravel and gray clay. The other one started in sand and gravel. All three bottomed in saprolite.

54-P - Duncans Creek (13, p 8)

Two places were sampled in Rutherford County from placer

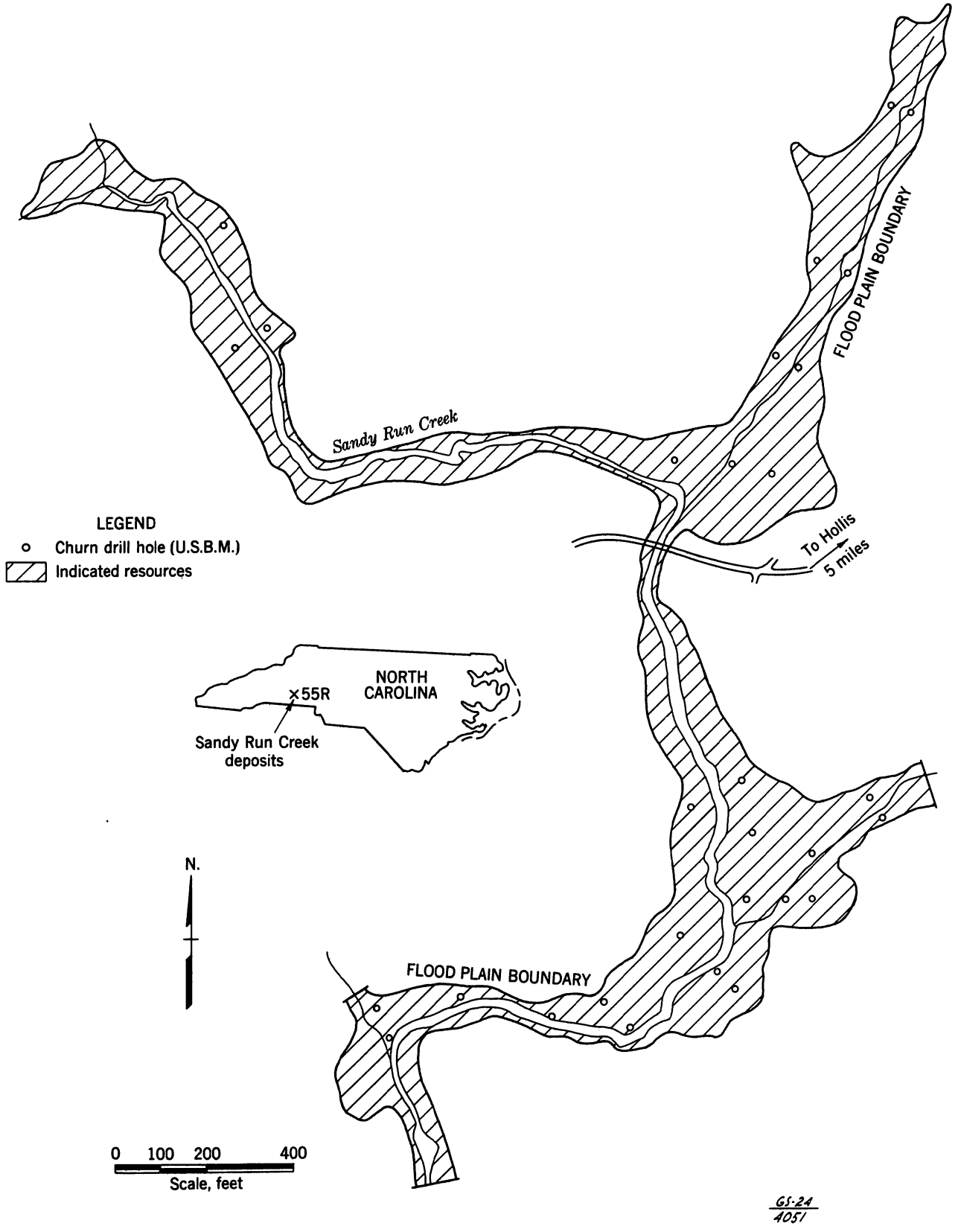

Figure 3.- Sandy Run Creek Deposit, Rutherford County, North Carolina

deposits on a branch of Duncans Creek. One was about 2 miles, and the other about 2-1/2 miles north of Hollis. The heavy mineral content averaged 0.4 percent.

55-R - Sandy Run (14)

The Sandy Run deposit in the flood plains of Sandy Run Creek and tributaries is about 4 miles (5 miles by road) south of Hollis in Rutherford County. The maximum extent of the deposit along Sandy Run Creek is about 3 miles, covering about 175 acres, of which 100 acres is considered inferred reserves. Estimates are based on the results of 30 churn drill holes covering the 75 acres of indicated reserves(Fig. 3). Exposed rocks in the Sandy Run Creek drainage area are biotite and sillimanite schists, and biotite gneiss. Pegmatite associated with quartz monazite, was also noted. The heavy mineral concentrate which represents 0.89 percent of the alluvium includes ilmenite, garnet, sillimanite, monazite, rutile, kyanite, and zircon. Of these, titanium minerals represent about 40 percent of the concentrate.

56-P - Webb Creek (13, p 8)

Two placer samples were obtained from Webb Creek and a tributary about 2 miles northwest of Ellenboro in Rutherford County. The average heavy mineral content was 0.9 percent.

57-P - Second Broad River (13, p 8)

A sample was taken from a branch of Second Broad River, about

2-1/2 miles southwest of Ellenboro, in Rutherford County. A heavy mineral content of 0.3 percent was reported.

58-P - Monazite Branch (13, p 8)

A heavy mineral content of 0.7 percent was reported at the placer prospect in Rutherford County on Monazite Branch 2-1/2 miles northeast of Ellenboro.

59-P - Sandy Run (13, p 8)

The average results of two placer prospects on Sandy Run in Cleveland County, 9 miles west of Shelby, and 1 mile north of U.S. Highway 74 showed 0.5 percent heavy minerals.

60-P - West Sandy Run (13, p 8)

Samples were taken on the west branch of Sandy Run in Cleveland County, 9 miles west of Shelby, and 1 mile south of U.S. Highway 74. Reported heavy minerals was 0.3 percent.

61-P - Beaver Dam Creek (13, p 8)

A heavy mineral content of 0.7 percent was reported at this placer prospect in Cleveland County on Beaver Dam Creek about 5-1/2 miles west of Shelby.

62-P - Little Hickory Creek (13, p 7)

A heavy mineral content of 0.3 percent was reported from this placer prospect on Little Hickory Creek in Cleveland County about

2-1/2 miles northeast of Shelby.

63-P - Hickory Creek (13, p 7)

A placer prospect on Hickory Creek 2 miles northeast of Shelby in Cleveland County showed 0.2 percent heavy minerals.

64-P - Brushy Creek Fork (13, p 7)

This placer prospect is located on a fork of Brushy Creek 4 miles northwest of Shelby in Cleveland County. A heavy mineral content of 1.8 percent was reported.

65-P - Brushy Creek Fork (13, p 7)

This placer prospect is 5-1/2 miles northwest of Shelby on a fork of Brushy Creek in Cleveland County. Six-tenths of a percent of heavy minerals was reported.

66-P - Grassy Creek (13, p 8)

A heavy mineral content of 0.5 percent was reported from a placer prospect on Grassy Creek in Cleveland County about 4 miles west of Lawndale.

67-P - Long Branch (13, p 7)

A placer prospect on Long Branch in Cleveland County about 4 miles east of Lawndale showed 0.1 percent heavy minerals.

68-P - West Buffalo Creek (13, p 8)

The west branch of Buffalo Creek was examined in Cleveland

County about 5 miles east of Lawndale. The placer showed 0.1 percent heavy minerals.

69-P - West Buffalo Creek (13, p 8)

A placer prospect further up the west branch of Buffalo Creek in Cleveland County 5 miles northeast of Lawndale showed 0.3 percent heavy minerals.

70-R - Buffalo Creek (15)

This flood plain placer deposit starts at the junction of Buffalo Creek and the tributary Glen Creek, and extends about 6,000 feet up each stream (fig. 4). The deposit is in Cleveland County 6 miles northeast of Lawndale. Seventeen churn drill holes provided the data for estimating 120 acres of indicated reserves averaging 11.2 feet thick. Granite gneiss determines the down-stream limit of the deposit. The heavy mineral concentrate which represents 1.44 percent of the alluvial material includes garnet, ilmenite, sillimanite, andalusite,monazite, rutile, staurolite, zircon, and ferromagnesian minerals. Of this 20.8 percent are titanium minerals.

70-P - Buffalo Creek (13, p 8)

The results of prospect sampling on west branch of Buffalo Creek about 1/2 mile down-stream from the stream junction was reported to show a concentrate of 0.4 percent, of which 61 percent was reported as monazite.

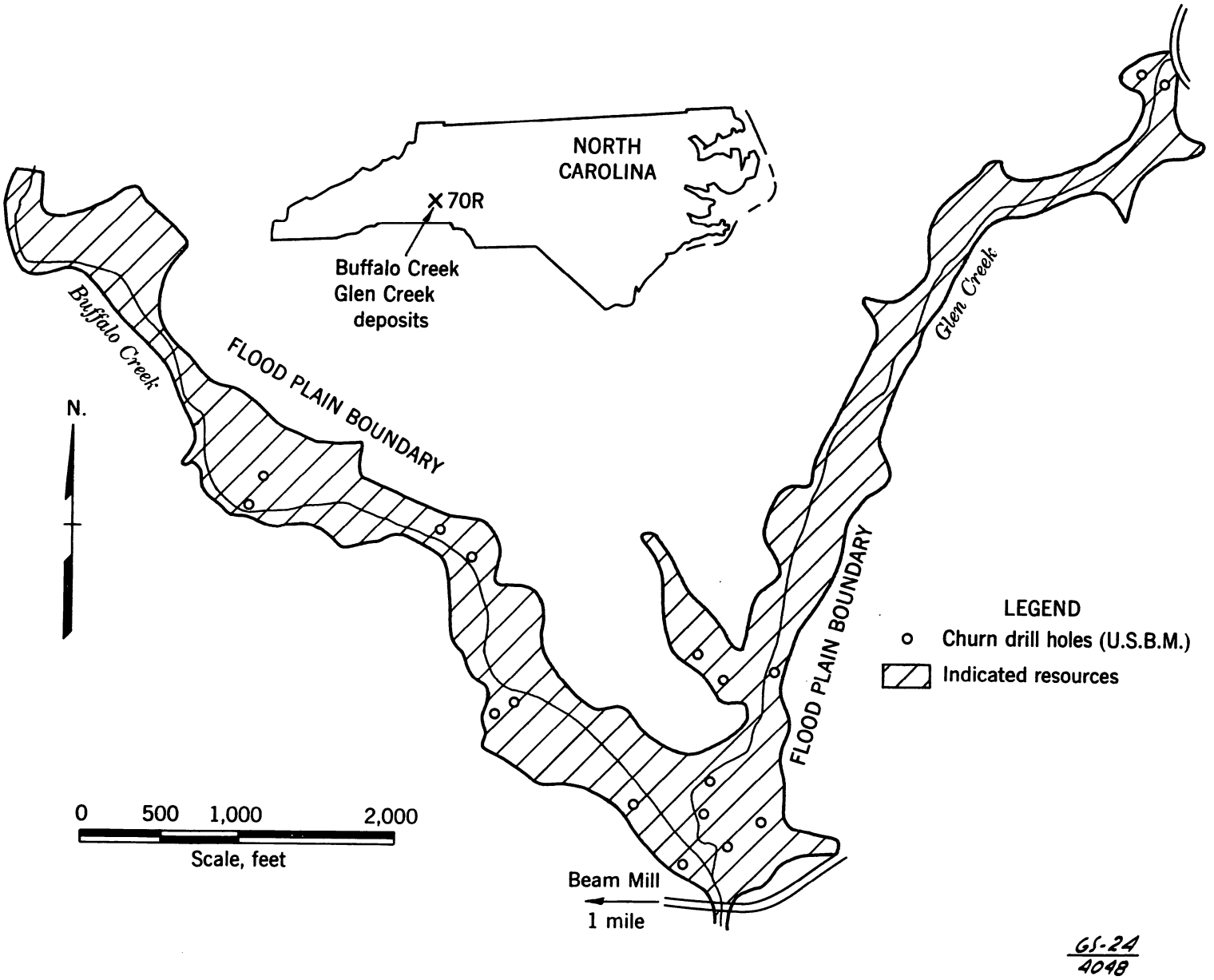

Figure 4.- Buffalo Creek and Glen Creek Deposits, Cleveland County, North Carolina

71-P - Maple and Knob Creeks (13, p 8)

Three placer prospects in the vicinity of Maple Creek and Knob Creek in Cleveland County from 3-1/2 to 4-1/2 miles northeast of Lawndale average 1.8 percent heavy minerals.

72-P - Crooked Run S. (13, p 8)

A placer prospect on a branch of Crooked Run in Cleveland County about 3-1/2 miles north of Lawndale showed 0.6 percent heavy minerals.

73-R - First Broad River and Tributaries (16)

The flood plains of the First Broad River and tributaries, Hinton Creek, Duncans Creek, and Wards Creek in Cleveland County compose this placer deposit. The down-stream limit of the deposit is at the junction of Broad River and Hinton Creek, about 5 miles northwest of Lawndale. About 5 miles of First Broad River, 2 miles of Hinton Creek, 1 mile of Duncans Creek, and 2-1/2 miles of Wards Creek flood plains were drilled with a churn drill (fig. 5).

Fifty-two churn drill holes control the estimates for about 530 acres of indicated reserves, averaging 22 feet in depth. Carolina gneiss was the predominate material drilled, and contained sillimanite. Ilmenite, garnet, quartz, kyanite-sillimanite , monazite, zircon, rutile, epidote , and ferromagnesian minerals compose most of the heavy mineral constituent, however, a large amount of marcasite was reported to occur in the Duncans Creek flood plain. Titanium minerals compose 34 percent of the concentrate, which in turn is

about 0.64 percent of the alluvium.

74-P - Crooked Run N.(13, p 7)

A heavy mineral content of 0.3 percent was reported from the placer prospect on a branch of Crooked Run in Cleveland County about 6-1/2 miles north Lawndale.

75- P - Bald Knob Creek (13, p 8)

A placer prospect on Bald Knob Creek in Cleveland County about 7 miles north of Lawndale showed 0.6 percent heavy minerals.

76-R - Knob Creek (17)

A placer deposit in Cleveland County begins about 7 miles north of Lawndale, and extends north with the flood plain of Knob Creek for a distance of 0.9 mile to State Highway 10 (fig. 6). Twenty-two holes provided the data for estimating 110 acres of indicated heavy mineral reserves, and 64 acres of inferred reserves, which average about 18.5 feet of minable alluvium. The predominant underlying formations are biotite gneiss and schist, sillimanite schists, and pegmatite related to quartz monzonite. The most prevalent minerals that are included in the concentrate are garnet, quartz, monazite, ilmenite, epidote, magnetite, zircon, and ferromagnesian minerals. Ilmenite composes 24.5 percent of the concentrate. Gold was reported found in the concentrate.

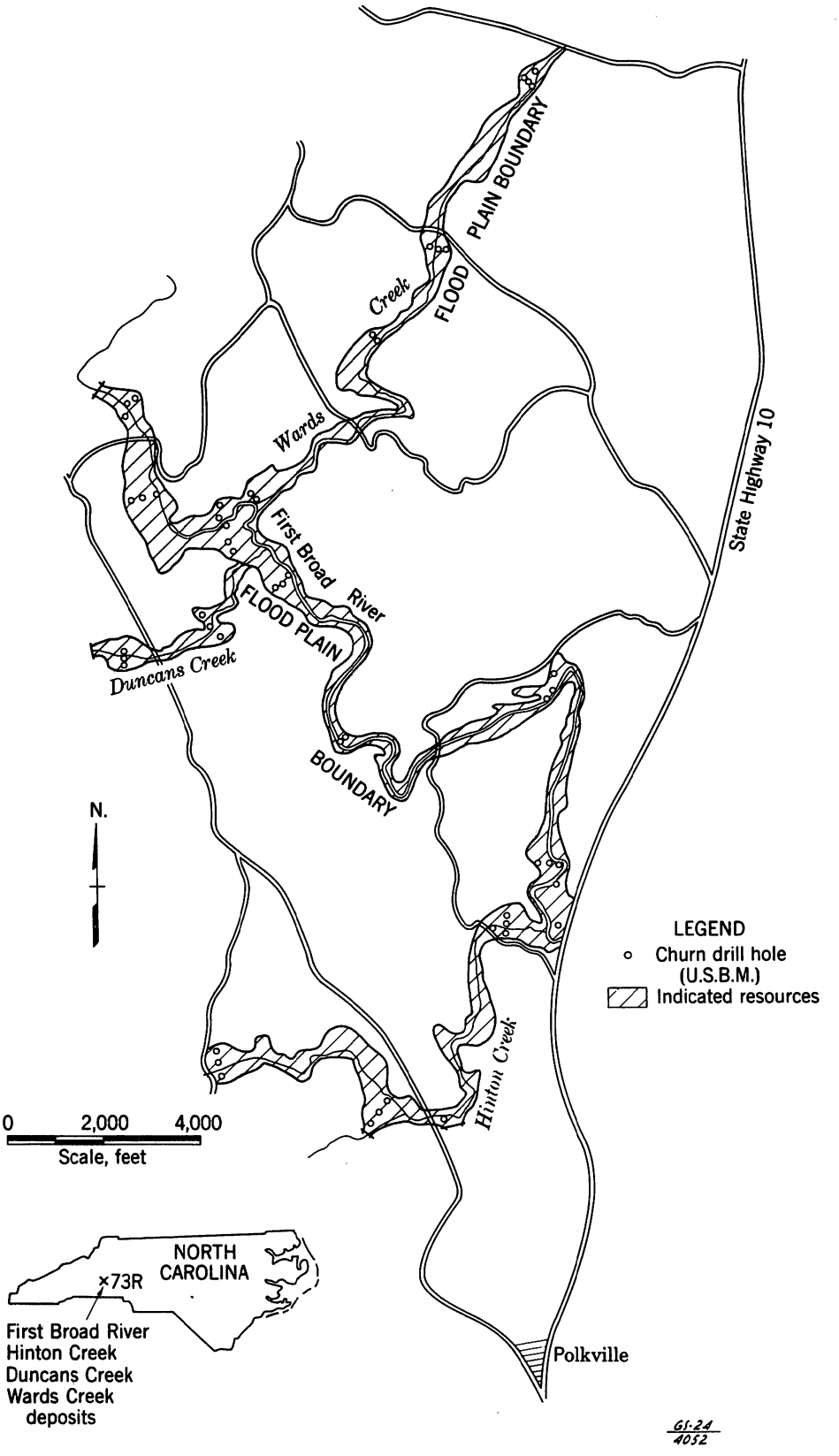

Figure 5.- First Broad River, Hinton Creek, Duncans Creek, and Wards Creek Deposits, Cleveland County, North Carolina

76-P - Knob Creek (13 p 7)

Results of prospect sampling on a west branch of Knob Creek were reported to show a concentrate of 0.3 percent, of which 56 percent was monazite.

77-P - East Knob Creek (13, p 7)

Two-tenths of a percent of heavy minerals was reported from this placer prospect on the east fork of Knob Creek in Cleveland County, about 9 miles north of Lawndale.

78-T - Indian Creek (5, p 83)

Titaniferous "ore is found as a float on the farm of Lawson Bess" near Indian Creek, 9 miles west of Lincolnton in Lincoln County. Analyses showed 2.40 percent TiO_2.

79-P - Camp Creek (13, p 8)

Heavy mineral content was reported to be 0.6 percent on Camp Creek, about 14 miles southeast of Morganton, in Burke County.

80- P - Rock Creek (13, p 8)

A heavy mineral content of 0.6 percent was reported from the placer prospect on Rock Creek in Burke County about 9 miles southeast of Morganton.

81-D - Halls Creek

Three holes were drilled along Halls Creek about 10 miles

southwest of Morganton, Burke County. One was drilled at the junction of Halls Creek and Silver Creek. The other two were drilled 2 miles and 2-1/2 miles up-stream from the junction. The holes ranged in depth from 12 feet to 21 feet, with an average thickness of 13 feet. Laboratory reports showed an average heavy mineral content of about 1.1 percent, containing about 42 percent ilmenite. Occurrence of gold was also reported.

Two of the holes started in top soil, fine sand, and blue clay. The other started in sand and gravel. All three bottomed in ~~soft gray or brown saprolite.~~

~~82-R~~ - ~~Silver Creek~~ (12)

A placer deposit in Burke County, in the flood plains of Silver Creek and a tributary Clear Creek, extends about 3.2 miles up-stream along Silver Creek and Clear Creek from a point about 3 miles southeast of Morganton (Fig. 7). Four churn drill holes control the estimate for 68 acres of indicated heavy mineral reserves limited to within 700 feet from the drill holes by geologic evidence. Inferred reserves cover 353 acres with an average thickness of 20 feet. The deposit is underlain by metamorphic rocks consisting of gneiss, schist, and pegmatite. The most prevalent heavy minerals in the concentrate, which is 0.45 percent of the alluvium, are ilmenite, quartz, epidote, magnetite, zircon, and monazite. Titanium minerals compose 34 percent of the concentrate. Gold was reported to occur in the concentrate.

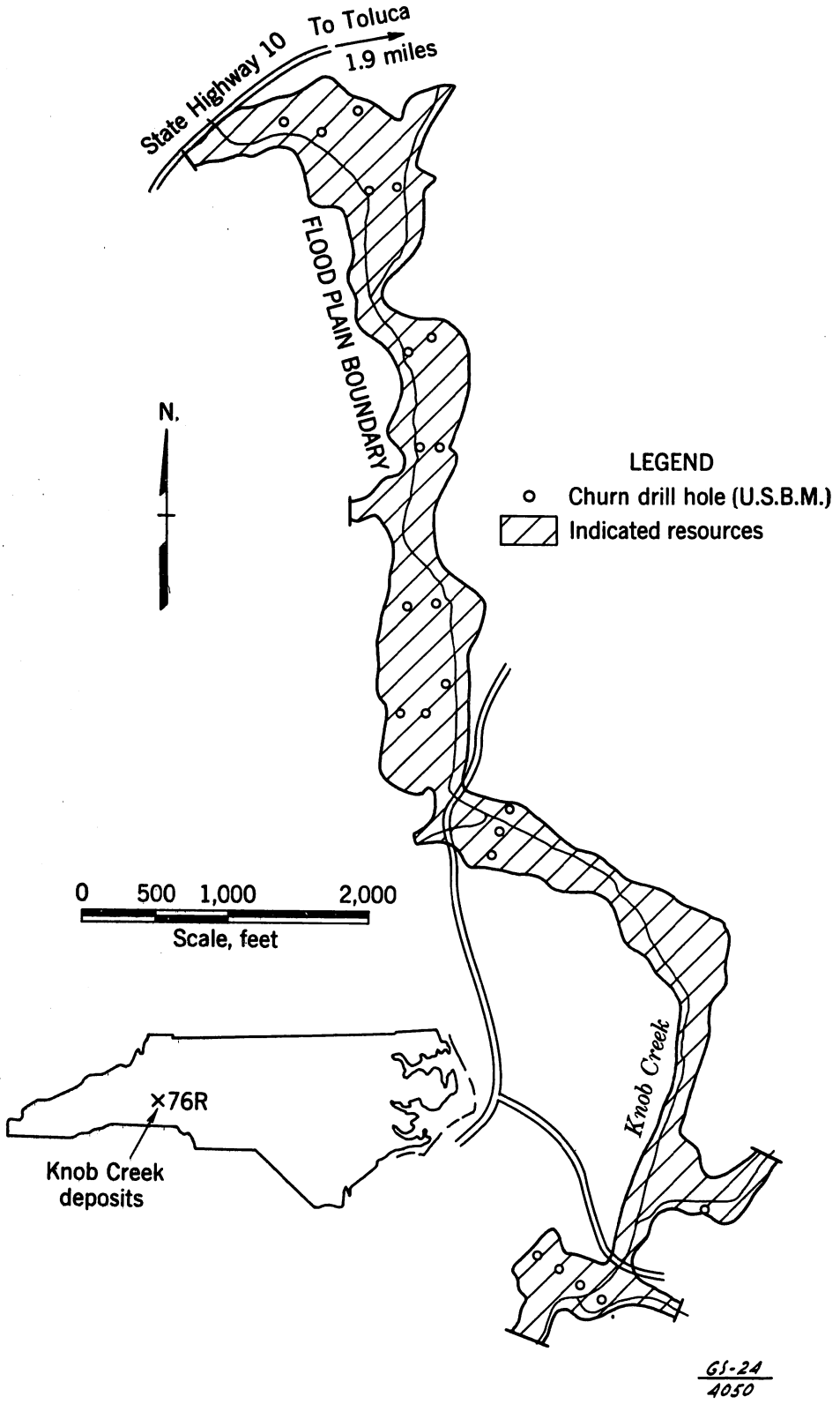

Figure 6.- Knob Creek Deposit, Cleveland County, North Carolina

82-P - Silver Creek (13, p 8)

Results of prospect sampling on a south branch of Silver Creek were reported to show a concentrate of 0.3 percent, containing 47 percent monazite.

83-D - Catawba River (12, pp 26, 27)

Three holes were drilled in the Quarker Meadow flood plain of the Catawba River near the west city limits of Morganton, Burke County. The depth of the holes ranged from 23 feet to 33 feet , and averaged about 27 feet of minable alluvium. The heavy mineral concentrate averaged about 0.55 percent of the sampled material. Of this, titanium bearing minerals composed 49 percent.

84-T - Forney Mine (5, p 86)

An analysis of a sample from the Forney Mine in Catawba County 1 mile south of Maiden recorded 1.6 percent TiO_2.

85-G - Hogan Creek (8, p 62)

A stream bar near State Highway 10, 5 miles east of Newton in Catawba County was sampled. The concentrate contained about 31 percent titanium minerals.

86-G - Duck Creek (8, p 61)

Samples were obtained from a stream bar in Duck Creek and nearby State workings 8 miles west of Taylorsville in Alexander

County. Ilmenite in the concentrate averaged 16 percent.

87-P - Third Creek (13, p 8)

A placer prospect on Third Creek in Alexander County, 8 miles southwest of Taylorsville was reported to show 0.8 percent heavy minerals.

88-T - Bear Creek (5,p 86)(6, p 84)(7, p 238)

Near the mouth of Bear Creek in Davie County, 5 miles south of Mocksville, "two or three shallow pits were made" about 1880. TiO_2 content was reported to be 10.32 percent.

89-T - Dutchman's Creek (5, p 86) (6, p 85)(7,p 239)

"Several pits and a shaft 20 feet deep were sunk" on a hill-top above Dutchman's Creek in Davie County 7- 1/2 miles northeast of Mocksville. TiO_2 content was reported to be 8 percent.

90-T - Charles (5, p 82)(6, p 224)(7, p 234)

Titaniferous ore containing 11.95 percent TiO_2 was reported under the name of Elisha Charles in Guilford County, 6 miles north of High Point.

91-T - Cook (5, p 82)(6, p 224)(7, p 231)

Titaniferous ore containing 13.28 percent TiO_2 was reported under the name of Widow Cook's Place, 7 miles north of High Point in Guilford County.

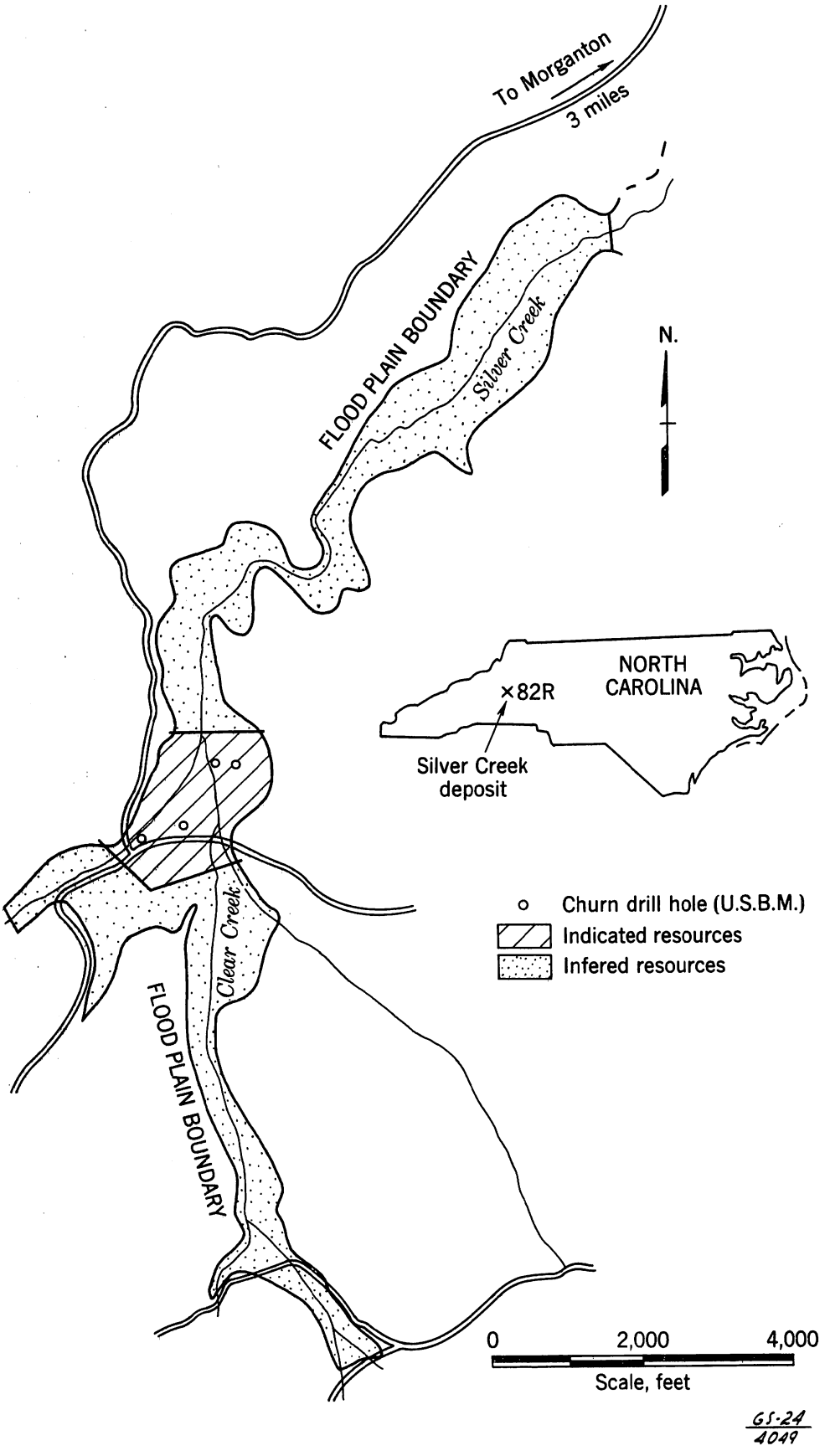

Figure 7.- Silver Creek Deposit, Burke County, North Carolina

92-T - Tuscarora Mine (5, pp 87-89)(7, p 234)

The Tuscarora mine is about 8 miles west of Greensboro, Guilford County. "It seems that the titaniferous ores could be readily smelted in the old Catalon forges", and "considerable iron is said to have been made". The average of 3 reported analyses showed 13.59 percent TiO_2.

93-T - Trueblood (5, p 89)(6, p 62)(7, p 231)

Ore "very similar in appearance" to that of the Tuscarora mine " except that etched sections do not show the intergrowths as abundantly" was reported at the Trueblood plantation in Guilford County 7 miles west of Greensboro, and 1 mile northeast of the Tuscarora mine.

94-T - Lewis (5, p 83)(6, p 230)(7, p 230)

Titaniferous ore containing 12.27 percent TiO_2 was reported to occur at the W. A. Lewis place in Guilford County about 9 miles north of Greensboro.

95-T - Shaw Mine (5, p 83)(6, p 230)(7, p 237)

The Shaw mine where "some pits on the property were worked during Revolutionary times" is in Rockingham County, about 10 miles southwest of Reidsville. TiO_2 of the titaniferous ore was reported to be 14.46 percent.

95-T - Dannemora Mine (5, p 90)(6, p 230)(7, p 234)

The Dannemora mine is Rockingham County about 7 miles southwest of Reidsville "was in operation in 1880 when it was visited by Bailey Willis, who reported the ore deposit to be 125 feet long, 80 feet wide on the incline used and 12 feet thick". An analysis report showed that the titaniferous ore contained 13.74 percent TiO_2.

97-T - Hopkins (5, p 83)(7, p 230)

A titaniferous sample from P. Hopkins farm near the Haw River in Rockingham County 6 miles southwest of Reidville showed a content of 13.92 percent TiO_2.

98-T - Apple (5, pp 89-90)(7, p 238)

Two titaniferous samples obtained from the Apple Plantation near the Haw River in Rockingham County about 7 miles south of Reidville were reported as containing an average TiO_2 content of 1.60 percent.

99-G - Nicks Creek (8, p 64)

A sample was obtained from a stream bar in Nicks Creek about 3 miles south of Carthage in Moore County. The concentrate showed 59 percent titanium minerals.

100-G - Little River (8, p 63)

Little River and a nearby creek were sampled in Hoke County

about 18 miles northwest of Fayetteville. The concentrates averaged about 58 percent titanium minerals.

101-G - Cumberland Sand and Gravel (8, p 62)

Cumberland Sand and Gravel Co. pit and a nearby river bar in Cumberland County about 3 miles northwest of Fort Bragg were sampled. The concentrates averaged about 51 percent titanium minerals.

102- Allied-Kennecott Titanium Corp.

This property is a 1,736 acre tract purchased by Allied-Kennecott Titanium Corporation in New Hanover County fronting on the Cape Fear River about 5 miles south of Wilmington. Deeds for property were registered during the years of 1957 and 1958. Although the erection of a titanium processing plant was originally indicated, no development was in evidence as of the end of 1960.

103-D - New Hanover (8, p 68)

Two holes were drilled to depths of 35 feet and 15 feet along U.S. Highway 17, about 4 and 6 miles east of Wilmington in New Hanover County. One hole was started in swamp muck and brown sand, and cut through white and gray clay; it bottomed in blue and green clay. The other hole started in gray clay and brown sand, and bottomed in hard white and brown clay. Records showed that the top 9 feet averaged about 3 percent heavy minerals.

104-S - Topsail (10, p 27)

"A small but relatively high concentration" (of heavy minerals) "is located near the northern end of Topsail Island in Onslow County."

105-D - Morehead (8, p 68)

Five holes were reported to have been drilled in Carteret County. Three of the holes were located from 2 to 5 miles west of Morehead City. The depth of the holes ranged from 18 to 35 feet. The holes started in fine white and brown sand. Four of the holes bottomed in a varied combination of gray, blue, or green clay, and the other one bottomed in brown sand and clay. Heavy minerals were reported at depths ranging from 5 to 20 feet, and averaged about 0.9 percent of the material drilled.

106-D - No. 1 Township

Courthouse records show that National Lead Company secured titanium exploration leases on about 1,000 acres in No. 1 Township in Pamlico County. Of this, the company obtained deeds on 860 acres. A Federal Bureau of Mines jet hole 25 feet deep was reported along side of State Road 306, about 500 feet south of the Beaufort County line (8, p 66). The hole started in brown and yellow sand. After passing through white sand and brown clay, it bottomed in gray clay and white sand. The top 11.5 feet averaged about 3.8 percent heavy minerals. The full 25 feet averaged about 2.5 percent heavy minerals.

107-D - 108-D - Richland

Records in the Beaufort County courthouse show that National Lead Company had as much as 1,600 acres leased for titanium exploration, which was later reduced to about 1,200 acres. They also obtained deed in fee simple on an additional 1,700 acres. The tracts were reported as situated in Richland Township.

"On November 21, 1951, the State granted to National Lead Company a lease to investigate the ilmenite sands along the coastal areas of North Carolina, and a similar lease was granted to Burnup and Sims, Inc. on March 5, 1952". "Concentrations of possible economic interest were found along some of the old beach roads inland from Pamlico Sound" (10, p 27).

Federal Bureau of Mines records show 5 holes drilled in the same township (8, p 66). Two of the holes along the side of State Route 306 just north of the Pamlico County line showed an average heavy mineral content of about 4.0 percent to a depth of 20 feet. The upper part of the holes was mostly in gray, white, or brown sand. One hole bottomed at 35 feet in blue clay. The other bottomed in yellow to gray clay at a depth of 30 feet.

The three holes were reported as starting in fine white sand, and bottomed at depths of 25 feet in more white sand with some gray clay in one of the holes. The heavy mineral content averaged about 2.1 percent in the top 15 feet.

109 - Chowan

National Lead Company secured leases to explore for ilmenite on 334 acres in Chowan County. Fifty-four acres are in Second Township, and 280 acres are in Third Township.

110-D - Perquimans

The Federal Bureau of Mines drilled 4 holes in Perquimans County. The descriptions of the locations were not sufficiently specific to locate on a map. The holes varied in depth from 17 to 35 feet, and started in white sand and bottomed in gray clay. Blue clay showed in the bottom of one hole. Total heavy mineral content averaged about 3 percent. The top 13 feet averaged about 4.4 percent of heavy minerals.

111 - Albermarle Sound (10, p 27)

"Since 1942, there has been considerable interest in the ilmenite-bearing sands of the Coastal Plain. On January 26, 1942, E. I. duPont de Nemours and Co. obtained a non-exclusive lease from the State of North Carolina to prospect for ilmenite in and along Albermarle Sound."

MINING AND BENEFICATION

The Yadkin Valley Ilmenite Mine, as described under 43-T, was the only commercial operation for the recovery of titanium minerals in North Carolina during recent years. Operations were

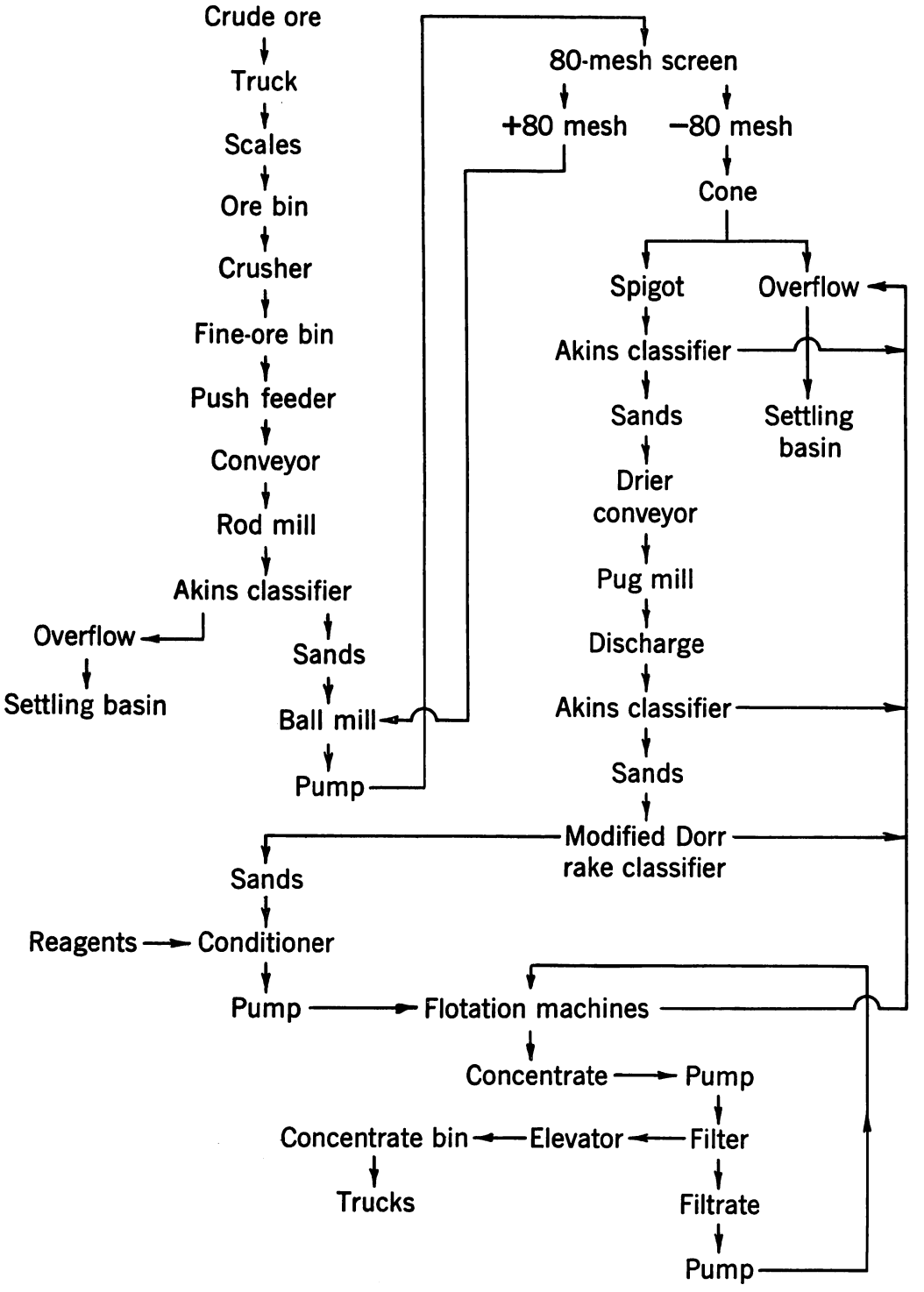

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Figure 8.- Mill Flow Sheet Yadkin Valley Ilmenite Mine, Caldwell County, North Carolina

discontinued in 1952, and information about the operation is limited. The method of mining was open pit, but no data are available on the details such as ground breaking, loading, haulage to the mill, or beneficiation .

Although the mill building was still standing when visited in 1961, all machinery had been removed, leaving no evidence of milling methods. A flow sheet of the mill was included in an unpublished Federal Bureau of Mines report (11)(fig. 8). Since the ore had little or no magnetite, the flow sheet shows that the ore was crushed and slimes removed. The ore was crushed and screened to minus 80 mesh, and processed by cone classifiers. Final concentration was by flotation.

The details on beneficiation were not discussed in the report (11). However, flotation tests were discussed in a paper by L. L. McMurray (18) in which he stated that " either fatty acid and alkali" could be used to float the ilmenite, or "an amine and acid could be used to remove the gangue selectively, leaving the ilmenite as tails".

CONCLUSIONS

Conclusions derived from examining the available data indicate that the Yadkin River deposit has the best possibilities as a hard rock operation for the recovery of ilmenite. As beneficiation and metallurgical research advance on the separation of minerals in the ore and recovery of TiO_2, the titaniferous deposits in North Carolina represent potential value. Examination of records of placer deposits indicated that the coastal areas are the most favorable, although

available investigative data from those areas were insufficient for a conclusive statement.

Some of the published data upon which this report is based were the results of prospect sampling which showed considerable difference when compared with later drilled sampling. The heavy mineral portion or concentrate of many of the placer prospect samples (13) was reported to contain in excess of 50 percent monazite (table 1). This implied that titanium minerals were relatively scarce, since the total content of ilmenite, rutile, zircon, and monazite seldom exceed 60 percent of the concentrate. However, later drilling in some of the areas was reported to show less than 10 percent monazite in the concentrate. The results of drilled sampling should be given more consideration than the results of prospect sampling identified in the tables with the suffix P. At the same time, it was noted that the amount of concentrate per cubic yard was reported much lower in the prospect samples than in the results of later drilling. Most of the inconsistencies occurred in the samples from Cleveland and Rutherford Counties.

The results of 15 Federal Bureau of Mines drill holes scattered over the coastal counties in North Carolina show that the coastal deposits contain a higher percentage of heavy minerals than the interior up-stream placer deposits. South Carolina records show that there is a marked tendency for the heavy minerals along the coast to contain about 10 percent more ilmenite than the interior stream placers.

Although the Federal Bureau of Mines did not explore the

coastal counties sufficiently to obtain suitable data for reserve estimates, it is known that National Lead Company and E. I duPont de Nemours and Company explored a considerable amount of the coastal area. This is based on courthouse records of leases, options, and deeds. The details of this is covered under description of the related deposits. The drilling data was not available.

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