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U.S. GEOLOGICAL SURVEY CIRCULAR 944

The Conterminous United States Mineral Assessment Program—Background Information to Accompany Folio of Geologic, Geophysical, Geochemical, Mineral-Occurrence, Mineral-Resource Potential, and Mineral-Production Maps of the Charlotte 1° X 2° Quadrangle, North Carolina and South Carolina

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CONTENTS

ILLUSTRATIONS

TABLE

The Conterminous United States Mineral Assessment Program—Background Information to Accompany Folio of Geologic, Geophysical, Geochemical, Mineral-Occurrence, Mineral-Resource Potential, and Mineral-Production Maps of the Charlotte 1° × 2° Quadrangle, North Carolina and South Carolina

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ABSTRACT

This Circular and the folio of separately published maps described herein are part of a series of reports compiled under the Conterminous United States Mineral Assessment Program (CUSMAP). The folio on the Charlotte 1°×2° quadrangle, North Carolina and South Carolina, includes (1) a geologic map; (2) four geophysical maps; (3) geochemical maps for metamorphic heavy minerals, copper, lead and artifacts, zinc, gold, tin, beryllium, niobium, tungsten, molybdenum, titanium, cobalt, lithium, barium, antimony-arsenic-bismuth-cadmium, thorium-cerium-monazite, and limonite; (4) mineral-occurrence maps for kyanite-sillimanite-lithium-mica-feldspar-copper-lead-zinc, gold-quartz-barite-fluorite, iron-thorium-tin-niobium, and construction materials-gemstones; (5) mineral-resource potential maps for copper-lead-zinc-combined base metals, gold, tin-tungsten, beryllium-molybdenum-niobium, lithium-kyanite-sillimanite-barite, thorium (monazite)-uranium, and construction materials; and (6) mineral-production maps.

The Charlotte quadrangle is mainly within the Piedmont physiographic province and extends from near the Coastal Plain on the southeast into the Blue Ridge province on the northwest for a short distance. Parts of six lithotectonic belts are present—the Blue Ridge, the Inner Piedmont, the Kings Mountain belt, the Charlotte belt, the Carolina slate belt, and the Wadesboro basin. Igneous, metamorphic, and sedimentary rocks are present and range in age from Proterozoic to Mesozoic; alluvial sediments of Quaternary age occur along rivers and larger streams.

Rocks of the Blue Ridge include Middle Proterozoic granitoid gneiss intruded by Late Proterozoic granite; Late Proterozoic paragneiss, schist, and other metasedimentary and metavolcaniclastic rocks (Ashe and Grandfather Mountain Formations); Late Proterozoic and Early Cambrian metasedimentary rocks (Chilhowee Group); and Early Cambrian sedimentary rocks (Shady Dolomite). Paleozoic granites intrude the Proterozoic rocks. The Inner Piedmont contains noncarbonate metasedimentary rocks and amphibolite of medium to high metamorphic grades. These rocks are intruded by the Toluca Granite and Henderson Gneiss of Cambrian and Ordovician(?) age. The Charlotte belt consists largely of Late Proterozoic to Late Paleozoic granitic and gabbroic plutonic rocks and intervening enclaves of metasedimentary and metavolcanic rocks. The narrow Kings Mountain belt is located between the Charlotte and the Inner Piedmont belts and contains mainly Late Proterozoic metasedimentary rocks and plutonic rocks similar to those of the Charlotte belt. The Carolina slate belt, flanking the Charlotte belt on the east, contains weakly metamorphosed volcanic and sedimentary rocks. East of this belt, at the southeast corner of the quadrangle, is the Wadesboro basin, which has continental sedimentary rocks of Triassic age.

Layered rocks westward from and in the Charlotte belt are complexly folded, are steeply dipping, and in the Blue Ridge and Inner Piedmont are contained within major thrust slices. Rocks of the Carolina slate belt are gently folded. Rocks of the Wadesboro basin occur in downfaulted blocks.

The geophysical surveys of the Charlotte quadrangle consisted of Bouguer gravity, aeromagnetic, and aeroradioactivity surveys and used both newly obtained data and information from prior work. The gravity survey disclosed a distinct northeast-trending, northwest-decreasing gradient, which is part of the major gravity gradient that extends the length of the Appalachian Mountains. Granitic plutons of the Charlotte belt, in particular, are marked by gravity lows, and gabbro plutons, by highs. Several of the geologic belts display distinct magnetic character. The aeroradioactivity surveys showed a swath of consistently high gamma-ray intensities along the central part of the Inner Piedmont belt; these high intensities correspond to the so-called monazite belt. Oval patterns of high gamma-ray readings helped to define the position and margins of many granitic plutons, especially in the Charlotte belt.

The geochemical surveys of the Charlotte quadrangle were based on about 2,600 heavy-mineral-concentrate samples obtained from stream sediments. Three previously unsuspected geochemical features were found. They were (1) widespread tin mineralization, mainly westward from the Kings Mountain belt to the west edge of the quadrangle; (2) cobalt, associated with niobium, south of Salisbury, N.C., and not so associated, east of Gaffney, S.C.; and (3) base-metal mineralization (marked by high zinc, lead, and cadmium) in the northeast corner of the

quadrangle. Tin was found to be associated also with the Brown Mountain granitic pluton in the northwest part of the quadrangle and with the Salisbury pluton in the Charlotte belt.

The mineral-occurrence maps were computer printed from data entered in the U.S. Geological Survey Computerized Resource Information Bank.

The mineral-resource potential maps are based on data about (1) the occurrence of appropriate minerals (mineralization), (2) the presence of geochemical anomalies, (3) the presence of heavy-mineral anomalies, and (4) the presence of favorable host rock. Positive indications of mineral-resource potential are shown on most of the maps as "high" (representing a combination of appropriate mineral occurrence and favorable host rock), "moderate" (representing a combination of a geochemical and (or) heavy-mineral anomaly and favorable host rock), or "low" (representing any of the preceding factors alone). Geophysical anomalies have not been used to define mineral-resource potential but have been of indirect importance in helping to determine areas underlain by certain geologic units, particularly plutons. The data available for some mineral commodities warrant designating areas as having resource potential or broad favorability but do not warrant indicating degrees of potential.

The presence of certain heavy minerals in the concentrate samples has been a factor in determining resource potential, especially the presence of gold, scheelite (for tungsten), and monazite (for thorium). In addition to data obtained during CUSMAP, geochemical data obtained by the National Uranium Resource Evaluation (NURE) of the U.S. Department of Energy are shown on some of the mineral-resource potential maps. NURE data included on the maps for beryllium-molybdenum-niobium, lead, thorium, tin, tungsten, uranium, and zinc could aid in mineral exploration, and have been partly the basis for selecting the areas of resource potential shown on the maps for thorium and uranium.

The mineral-production maps use the unit regional value approach of J. C. Griffiths to show the distribution of quantity and value of reported past production of mineral commodities through 1978. Tables and graphs used with the maps illustrate variations in production. The mineral-production study is based primarily on data collected by the U.S. Bureau of Mines for counties located entirely or partly within the Charlotte quadrangle.

INTRODUCTION

This Circular, as well as a folio of separately published maps (table 1), is part of a series of U.S. Geological Survey reports that contain information on the mineral-resource potential of the conterminous United States. The studies described in this Circular were carried out in the Charlotte 1°×2° quadrangle in North Carolina and South Carolina. This Circular and the folio maps were compiled under the Conterminous United States Mineral Assessment Program (CUSMAP). CUSMAP is intended to provide regional mineral assessment information to assist in the formulation of a sound long-range national minerals policy and to assist Federal, State, and local governments in making decisions about land use. In addition, the products of CUSMAP are intended to increase geological, geochemical, and geophysical knowledge of the conterminous United States. In accomplishing these goals, the program provides regional geologic and mineral resource frames of reference for specific studies, such as the mineral assessment of wilderness areas, and for mineral exploration.

LOCATION AND GEOGRAPHY

The Charlotte 1°×2° quadrangle is located in south-central North Carolina and adjacent parts of South Carolina (fig. 1). The quadrangle covers approximately 20,375 km², between lat 35° and 36° and long 80° and 82°. Most of the quadrangle is within the Piedmont physiographic province; a small area in the northwest corner is in the Blue Ridge province, and the Atlantic Coastal Plain is a short distance beyond the southeast corner of the quadrangle. Most of the area has a gently rolling, moderately dissected topography that rises gradually to the northwest from about 75 to 300 m above sea level but has only about 30 to 50 m of local relief. In the northwest quarter of the quadrangle, the South Mountains reach elevations of about 775 m, and farther to the northwest mountains of the Blue Ridge belt reach elevations of 1,050 to 1,220 m.

Major streams flow generally south to southeast to the Atlantic Ocean. Drainage in the northwest corner of the quadrangle is westward toward the Gulf of Mexico. The major south- to southeast-flowing streams, the Broad, Catawba, and Pee Dee Rivers, have been dammed, and extensive reservoirs occur along their courses. The quadrangle contains many cities and towns and extensive urban areas, most notably along the corridor of Interstate Highway 85 and U.S. Highway 29 between the northeast and southwest corners of the quadrangle. Other major highways crossing parts of the area are Interstates 40 and 77 and U.S. Highways 52, 64, and 70; the quadrangle is interlaced by other highways and improved roads.

PREVIOUS WORK AND SOURCES OF INFORMATION

The area of the Charlotte quadrangle has attracted the interest of geologists for 100 years because of significant occurrences of various mineral commodities, most notably stone, clay, mica, feldspar, gold, silver, base metals, spodumene (lithium), monazite, barite, and kyanite. Many earlier studies focused on geology as related to one or another of these commodities (Brobst, 1962; Butler, 1981a; Espenshade and Potter, 1960; Griffitts and Olson, 1953; Kesler, 1942; Mertie, 1979; Nitze and Hanna, 1896; Overstreet and others, 1968).

Parts of six major geologic belts are present in the Charlotte quadrangle—the Blue Ridge, the Inner Piedmont, the Kings Mountain belt, the Charlotte belt, the Carolina slate belt, and the Wadesboro basin. Many studies have been made of the major geologic belts, particularly of the stratigraphy and structure of volcanic rocks and related sedimentary rocks of the Carolina slate belt (Seiders and Wright, 1977; Stromquist and Sundelius, 1969), stratigraphy and structure in the Blue Ridge and Inner Piedmont (Bryant and Reed, 1970; Butler, 1973; Reed, 1964), description and origin of the Brevard zone separating the Blue Ridge and Inner Piedmont (Cook and others, 1979; Clark and others, 1978), and the nature and age of plutons in the Piedmont (Charlotte belt and other belts) and in the Blue Ridge (Fullagar, 1971; Fullagar and Butler, 1979; Kish, 1976, 1977; Speer and others, 1979). Horton (1977) studied the Kings Mountain belt just prior to the beginning of the CUSMAP study and continued this work under CUSMAP.

Only in the presentation of certain geochemical data collected during the program for a National Uranium Resource Evaluation (NURE) (Heffner and Ferguson, 1978) has the Charlotte quadrangle as a whole been the specific subject of an investigation.

PRESENT INVESTIGATION

The present investigation has been an interdisciplinary study of geology, geophysics, geochemistry, and mineral deposits. The geologic study combines data compiled from earlier work with new information obtained during CUSMAP investigations since 1977. Extensive new mapping was done in the Inner Piedmont and Charlotte belts during CUSMAP, and a study of the Kings Mountain belt begun before CUSMAP by Horton (1977) was continued under the program. Gravity, aeroradiometric, and aeromagnetic surveys (Wilson and Daniels, 1980; Daniels and Zietz, 1981a, b; 1982) were particularly helpful in defining boundaries of major belts and in outlining plutons in the Charlotte belt. The geochemical survey was conducted by analyzing various magnetic fractions of pan concentrate samples of stream sediment and identifying their principal heavy-mineral constituents. This type of survey is the most practical means of conducting a geochemical study of a large area in a short time. Semiquantitative spectrographic analyses provide data on the abundances of some 30 trace elements in each sample. Anomalously high concentrations of certain trace elements help to identify areas of mineralization or potentially mineralized areas. The results of the geochemical survey are presented in a series of geochemical maps (table 1, OF 84-843-A to Q); most of the maps contain raw data on the abundance of a single trace element or compare or contrast data for two elements. Some of the geochemical maps contain data on distribution or concentrations of selected heavy minerals; a few maps show areas interpreted to be favorable for mineralization. Part of the present study involved a review of available information on mines, quarries, and abandoned prospects. The existence and locations of many mines and quarries were confirmed in the field, and data have been entered in the U.S. Geological Survey's Computerized Resource Information Bank (CRIB) (Calkins and others, 1973). Maps of mineral occurrences have been computer printed from CRIB for eight commodities or groups of commodities and are a part of this folio (table 1, map MF-1793).

Combinations of map data showing anomalous trace-element concentrations, mineral occurrences (that is, mines and prospects), and, in some cases, heavy-mineral concentrations are used in conjunction with the outlines of favorable geologic units to infer the resource potential of parts of the area for various metallic mineral commodities (table 1, maps I-1251-G to J; I-1251-L). Similar methods of combining data also are used to determine mineral-resource potential for several nonmetallic commodities (table 1, maps I-1251-K; I-1251-M), except that trace-element and heavy-mineral data for such commodities are generally lacking, insufficient, or inappropriate. As a result, inferred potential is based largely on the combined information about mineral occurrence and the distribution of favorable geologic units. The resource potential for sand and gravel, stone, and brick clay (large-volume construction materials) is assessed only in broad terms (table 1, map I-1251-M). Such materials are available essentially throughout the

TABLE 1.—*List of maps in Charlotte CUSMAP folio*

[Maps listed alphabetically by author(s) in References section, p. 13 to 18]

Number	Author(s)	Abbreviated title
Miscellaneous Investigations Series (I)		
I-1251-A	Wilson, F. A., and Daniels, D. L.	Simple Bouguer gravity map.
I-1251-B	Daniels, D. L., and Zietz, Isidore.	Aeromagnetic map (uncolored).
I-1251-C	Daniels, D. L., and Zietz, Isidore.	Aeromagnetic map (in color).
I-1251-D	Daniels, D. L., and Zietz, Isidore.	Aeroradioactivity map.
I-1251-E	Goldsmith, Richard, Milton, D. J., and Horton, J. W., Jr.	Geologic map and sections.
I-1251-F	DeYoung, J. H., Jr., Lee, M. P., and Dorian, J. P.	Mineral-production maps: Sheet 1—Summary of production by commodity categories. Sheets 2-3—Individual commodity production summaries.
I-1251-G	Gair, J. E., and Griffitts, W. R.	Mineral-resource potential for copper, lead, zinc, and combined base metals: Sheet 1—Copper and lead. Sheet 2—Zinc and combined base metals.
I-1251-H	Gair, J. E., and D'Agostino, J. P.	Mineral-resource potential for gold.
I-1251-I	Gair, J. E.	Mineral-resource potential for tin and tungsten.
I-1251-J	Gair, J. E.	Mineral-resource potential for beryllium, molybdenum, and niobium.
I-1251-K	Horton, J. W., Jr.	Mineral-resource potential for lithium, kyanite-sillimanite, and barite.
I-1251-L	Gair, J. E.	Mineral-resource potential for thorium (monazite) and uranium.
I-1251-M	Goldsmith, Richard, Gair, J. E., Horton, J. W., Jr., D'Agostino, J. P., and Milton, D. J.	Mineral-resource potential for construction materials: Sheet 1—Crushed stone. Sheet 2—Sand, gravel, and clay.
Miscellaneous Field Studies Maps (MF)		
MF-1793	D'Agostino, J. P., and Rowe, W.D., Jr.	Mineral Occurrences: Map 1—Kyanite, sillimanite, lithium, mica, feldspar, copper, lead, and zinc. Map 2—Gold, quartz, barite, and fluorite. Map 3—Iron, thorium, tin, and niobium. Map 4—Construction materials and gemstones.
Open-File Reports (OF 84-843-A to 84-843-Q)		
OF 84-843-A	Griffitts, W. R., Duttweiler, K. A., and Whitlow, J. W.	Distribution of garnet and other metamorphic minerals in heavy-mineral-concentrate samples.
OF 84-843-B	Griffitts, W. R., Whitlow, J. R., Duttweiler, K. A., Siems, D. F., and Botinelly, Theodore.	Distribution of copper in heavy-mineral-concentrate samples.
OF 84-843-C	Griffitts, W. R., Whitlow, J. W., Botinelly, Theodore, Duttweiler, K. A., Siems, D. F., and Wilch, L. 0.	Distribution of lead and artifacts in heavy-mineral-concentrate samples.
OF 84-843-D	Griffitts, W. R., Whitlow, J. W., Duttweiler, K. A., Siems, D. F., and Wilch, L. 0.	Distribution of zinc in heavy-mineral-concentrate samples.

TABLE 1.—*List of maps in Charlotte CUSMAP folio*—Continued

Open-File Reports (OF 84-843-A to 84-843-Q)—Continued		
OF 84-843-E	Whitlow, J. W., Duttweiler, K. A., Griffitts, W. R., and Siems, D. F.	Distribution of gold in heavy-mineral-concentrate samples.
OF 84-843-F	Griffitts, W. R., Whitlow, J. W., Duttweiler, K. A., Siems, D. F., and Wilch, L. 0.	Distribution of tin in heavy-mineral-concentrate samples.
OF 84-843-G	Griffitts, W. R., Duttweiler, K. A., Whitlow, J. W., Siems, D. F, and Hoffman, J. D.	Distribution of beryllium in heavy-mineral-concentrate samples.
OF 84-843-H	Griffitts, W. R., Whitlow, J. W., Duttweiler, K. A., Siems, D. F., and Wilch, L. 0.	Distribution of niobium in heavy-mineral-concentrate samples.
OF 84-843-I	Griffitts, W. R., Whitlow, J. W., Duttweiler, K. A., Siems, D. F., and Wilch, L. O.	Distribution of tungsten in heavy-mineral-concentrate samples.
OF-84-843-J	Griffitts, W. R., Duttweiler, K. A., Whitlow, J. W., Siems, D. F., and Hoffman, J. D.	Distribution of molybdenum in heavy-mineral-concentrate samples.
OF-84-843-K	Duttweiler, K. A., Botinelly, Theodore, Griffitts, W. R., and Whitlow, J. W.	Distribution of titanium in heavy-mineral-concentrate samples.
OF 84-843-L	Griffitts, W. R., Whitlow, J. W., Siems, D. F., Duttweiler, K. A., and Hoffman, J. D.	Distribution of cobalt in heavy-mineral-concentrate samples.
OF 84-843-M	Griffitts, W. R., and Hoffman, J. D.	Distribution of lithium.
OF 84-843-N	Griffitts, W. R., Duttweiler, K. A., Whitlow, J. W., Siems, D. F., and Wilch, L. O.	Distribution of barium in heavy-mineral-concentrate samples.
OF 84-843-O	Griffitts, W. R., Whitlow, J. W., Duttweiler, K. A., Siems, D. F., and Wilch, L. O.	Distribution of antimony, arsenic, bismuth, and cadmium in heavy-mineral-concentrate samples.
OF 84-843-P	Siems, D. F., Griffitts, W. R., Whitlow, J. W., and Duttweiler, K. A.	Thorium, cerium, and monazite survey.
OF 84-843-Q	Duttweiler, K. A., Griffitts, W. R., and Whitlow, J. W.	Distribution of limonite pellets in heavy-mineral-concentrate samples.

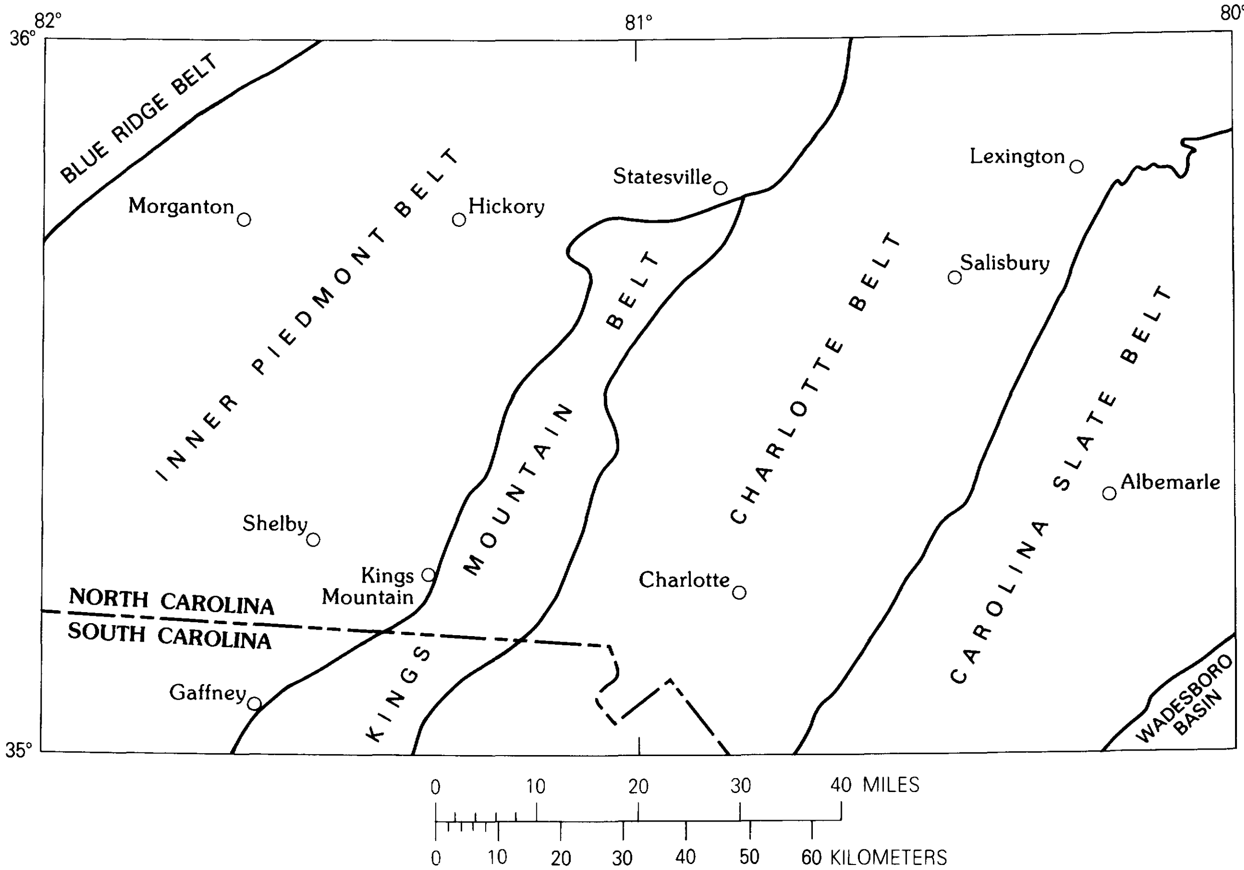

FIGURE 1.—Major lithotectonic belts in the Charlotte 1°×2° quadrangle, North Carolina and South Carolina.

area, and their resource potential may be as much a function of proximity to markets and variations in weathering as of bedrock geology. Nevertheless, formations from which resources of these construction materials have been obtained are accorded a somewhat greater potential for additional resources than are the other formations of the area.

GEOLOGIC MAP (TABLE 1, MAP I-1251-E)

The Charlotte quadrangle lies mainly in the Piedmont geomorphic province of the Appalachians, but the northwest corner of the quadrangle is in the Blue Ridge province. The quadrangle contains igneous, metamorphic, and sedimentary rocks that range in age from Proterozoic to Mesozoic. Outliers of coastal plain rocks in the southeast corner contain sediments of Cretaceous age. Alluvial sand and silt of Quaternary age flank the larger rivers and streams. The oldest rocks are granitoid gneisses of Middle Proterozoic age that occur in the Blue Ridge. Younger rocks in the Blue Ridge are (1) paragneiss and schist of the Late Proterozoic Ashe Formation; (2) phyllite, arkose, conglomerate, and volcaniclastic rocks that belong to the Late Proterozoic Grandfather Mountain Formation; (3) quartzite and shale of the Late Proterozoic and Early Cambrian Chilhowee Group; and (4) the Early Cambrian Shady Dolomite. Late Proterozoic granite intrudes the Middle Proterozoic rocks, and early or middle Paleozoic granite and pegmatite intrude the Proterozoic rocks.

The western part of the Piedmont, the Inner Piedmont, consists of Late Proterozoic and possibly Cambrian paragneiss, schist, quartzite, and amphibolite of medium to high metamorphic grade. These rocks are intruded by pre- or synmetamorphic masses of granite and granite gneiss, primarily the Toluca Granite and Henderson Gneiss of Cambrian and Ordovician(?) age. Postmetamorphic granite and pegmatite of

Mississippian age, the Cherryville Granite, intrude schist in the eastern part of the Inner Piedmont.

The central part of the Piedmont in the Charlotte quadrangle, the Charlotte belt, consists largely of plutonic rocks that range in age from Late Proterozoic to late Paleozoic. A suite of premetamorphic, Late Proterozoic and Cambrian(?) plutonic rocks, mostly quartz-diorite and granodiorite, but including gabbro and granite, occupies much of the Charlotte belt. This plutonic complex contains enclaves of metasedimentary and metavolcanic rocks that are most abundant toward the flanks. The older plutonic complex is intruded by middle Paleozoic plutons that range from gabbro and syenite to granite and granodiorite and by late Paleozoic plutons that are typically porphyritic granite. Flanking the Charlotte belt on the west is the narrow Kings Mountain belt, which contains low- to medium-grade metasedimentary rocks that include pebble metaconglomerate, marble, quartzite, and manganiferous schist, all of probable Late Proterozoic age. The Kings Mountain belt contains most of the same suites of plutonic rocks as the Charlotte belt; the largest pluton is the High Shoals Granite of Pennsylvanian age. Flanking the Charlotte belt on the east is the Carolina slate belt, which contains weakly metamorphosed sedimentary and volcanic rocks. The Uwharrie Formation of Late Proterozoic age, a volcanic unit that consists principally of rhyolitic rocks but also contains basaltic rocks, is overlain by the Albemarle Group of Late Proterozoic age. The Albemarle consists of mudstone, siltstone, graywacke, and subordinate tuffs, agglomerates, and hypabyssal intrusives.

Continental sedimentary rocks of Triassic age occupy the Wadesboro basin, part of which is in the southeast corner of the quadrangle, and a small part of the Davie County basin, which is present in the north-central margin of the quadrangle. The Triassic rocks consist of fanglomerate, conglomerate, arkosic sandstone, and siltstone. Overlapping the Triassic rocks in the Wadesboro basin are thin patches of poorly consolidated sands of the Late Cretaceous Middendorf Formation. Two swarms of diabase dikes of Triassic and Jurassic age occur in the quadrangle; one strikes north-northwesterly in the Carolina slate and Charlotte belts, and the other, northwesterly in the southern Charlotte, the Kings Mountain, and the Inner Piedmont belts. One of these dikes extends into the Blue Ridge.

Deformation of the rocks of the Charlotte quadrangle differs in style in the different belts. Rocks of the Blue Ridge and Inner Piedmont are parts of major thrust slices. In the Blue Ridge, a series of thrust plates is exposed in the Grandfather Mountain window, a regional-scale opening eroded through the thrust plates in the northwest corner of the quadrangle. The Brevard fault zone separates these slices of the Blue Ridge from the complexly deformed rocks of the Inner Piedmont. Older folds in the Inner Piedmont are typically isoclinal and have gently to moderately dipping axial surfaces; younger folds refold the older folds about more steeply dipping axial surfaces. The steeply dipping Kings Mountain shear zone separates the Inner Piedmont from the Kings Mountain belt. The strata in the Kings Mountain belt are complexly folded and steeply dipping. The north end of the Kings Mountain shear zone is truncated by the Eufola fault, which separates the Inner Piedmont from the Charlotte belt. The deformation pattern in the Charlotte belt is obscure but undoubtedly is more complex than that of the gently folded strata of the Carolina slate belt. These two belts are separated by the Silver Hill shear zone. The Triassic rocks occupy downfaulted blocks in the Proterozoic and early Paleozoic terrane. Undeformed Late Cretaceous sediments unconformably overlie the Triassic and older rocks.

GEOPHYSICAL INVESTIGATIONS (TABLE 1, MAPS I-1251-A TO D)

Early aeromagnetic surveys by the U.S. Geological Survey (Bates and Bell, 1965; Henderson and Gilbert, 1966) in the eastern part of the quadrangle were flown with 0.5-mi (0.8-km) flight-line spacing. Coverage of the quadrangle was completed by five additional aeromagnetic surveys flown at 1-mi (1.6-km) spacing by private contractors for the USGS CUSMAP program or for Federal-State cooperative programs. All surveys were flown at 500 ft (152 m) above ground to accommodate simultaneous airborne total-count, gamma-ray measurements. Gravity data available from studies in the Charlotte quadrangle completed prior to the start of the CUSMAP program were collected at about 1,800 stations (Snyder, 1963; Morgan and Mann, 1964; Watkins and Yuval, 1966; Best, Geddes, and Watkins, 1973; unpub. data, Defense Mapping Agency Gravity

Library, 6500 Brookes Lane, Washington, DC 20315). These data were supplemented by 1,286 new measurements taken throughout the rest of the quadrangle by F. A. Wilson of the U.S. Geological Survey (Wilson and Daniels, 1980; Wilson, 1981).

BOUGUER GRAVITY MAP (TABLE 1, MAP I-1251-A)

The major feature displayed on the gravity map of the Charlotte quadrangle is the long, northwest-decreasing slope, or gravity gradient, which has been recognized along the full length of the Appalachian Mountain system for many years. The gravity gradient is produced by an unknown, but certainly deep-seated, structure of major proportions. Superimposed upon this gradient are numerous anomalies of smaller dimensions, most of which correlate closely with anomalies present on the magnetic and radioactivity maps. These anomalies lie mostly within the Charlotte belt. Gravity highs mark the mafic rocks, largely gabbroic plutons, and lows indicate granitic plutons.

The geophysical maps separately and in combination with one another provide strong support for reconnaissance geologic mapping. These maps show structural trends and continuity of formations between exposures and give some indication of subsurface rock bodies.

AEROMAGNETIC MAPS (TABLE 1, MAPS I-1251-B AND C)

Colored and uncolored aeromagnetic maps were assembled from seven separate surveys after removal of the International Geomagnetic Reference Field and adjustment for level differences. On the colored map (I-1251-C), magnetic intensities are coded by colors of the spectrum, high being red and low being blue. Uncolored levels are either above the highest or below the lowest values in the color range and serve to emphasize the most anomalous values. Colors aid in comparison of intensity levels across the map and highlight long-wavelength anomalies. In contrast, short-wavelength magnetic anomalies and high gradient areas show more prominently on the uncolored contour map (I-1251-B).

Distinct magnetic character and texture are associated with several of the lithotectonic belts that cross the Charlotte quadrangle. Intense, short-wavelength magnetic high anomalies are confined to the Charlotte belt and are produced largely by gabbroic rocks of probable Paleozoic age, which are exposed or lie at shallow depths. Deep magnetic lows generated by postmetamorphic granitic plutons also are characteristic of the Charlotte belt. Contributing to the depth of these lows are (1) the large magnetic contrast between the nonmagnetic granitic country rocks and intensely magnetic country rocks and (2) the depth extent of the plutons. This depth extent is probably larger than in other belts. Narrow, linear magnetic anomalies having northeast trends characterize the Kings Mountain belt and have their origin in low-grade metasedimentary rocks folded tightly around nearly horizontal fold axes. Other linear magnetic anomalies that trend northwest across the Carolina slate belt mark a swarm of diabase dikes that are usually early Mesozoic in age in this region. These anomalies show clearly in the Carolina slate belt; the slate belt lacks other short-wavelength anomalies because of the absence of magnetite in the surface rocks. An intense long-wavelength anomaly, however, dominates the Carolina slate belt within the quadrangle; a corresponding gravity high indicates that the anomaly is probably caused by a large body of subsurface mafic rock lying at a depth of several kilometers.

The surface rocks of the Inner Piedmont belt in the western half of the quadrangle are also relatively nonmagnetic. A broad low along the axis of the belt indicates that rocks similar to those at the surface extend to considerable depth; the low also suggests a general synformal structure.

AERORADIOACTIVITY MAP (TABLE 1, MAP I-1251-D)

The colored aeroradioactivity map was assembled from seven separate, airborne, total-count, gamma-ray surveys acquired (with one exception) simultaneously with the aeromagnetic data. The map is a mosaic of individual surveys because reduced gamma-ray data from separate surveys cannot be joined directly if calibration and equipment specifications differ between surveys, as was the case here. Colors were assigned so that an approximate equivalence of intensity for each color is achieved across the quadrangle. In spite of the compromises required, the map clearly reflects regional and local geology, except over lakes and rivers.

The most intense gamma-ray anomalies occur in the Inner Piedmont belt as a broad swath of nearly continuous high level that is mostly central, but slightly oblique, to the belt. The high intensities sharply delineate an area of rocks called the monazite belt in which this rare-earth–thorium–phosphate mineral is unusually abundant. Anomaly intensities can be used, in this belt, as a direct indication of monazite abundance at the surface. Nearly all of the gamma-ray highs (many of which are circular to oval) in the Charlotte and Kings Mountain belts are generated largely by potassium sources. The highs accurately show late Paleozoic granitic plutons. The overall level of the Charlotte belt, however, is low due to the abundance of mafic rock.

GEOCHEMICAL AND HEAVY-MINERAL SURVEYS (TABLE 1, OPEN-FILE REPORTS OF 84–843–A TO Q)

Members of the U.S. Geological Survey have conducted heavy-mineral and geochemical studies in the western part of the Charlotte quadrangle (Overstreet and Griffitts, 1955; Overstreet and others, 1959, 1968; Overstreet and Bell, 1960; Bell and Overstreet, 1960). Information collected during these studies provided excellent background information that was used in planning the present study; many heavy-mineral concentrates made during the earlier studies were used in the present work. A geochemical survey of the Charlotte quadrangle made on behalf of the U.S. Department of Energy by Van Price, Jr., and his associates, and reported by Ferguson (1979) and Heffner and Ferguson (1978), provided much useful data about the metals in the minus 100-mesh component of stream sediment.

The present geochemical and heavy-mineral investigation is based upon the sampling and analysis of stream sediments. Samples were taken at about 2,600 sites within 2 mi (3.2 km) of the heads of streams. About 10 lb (4.5 kg) of unsifted gravel were panned at each site to separate the heavy minerals. The heavy-mineral concentrates were sieved to separate the largest grains; then the remaining quartz and other light minerals were removed with bromoform. Each heavy-mineral concentrate was freed of magnetite, then passed through a Frantz Isodynamic separator at current settings of 0.5 and 1 A, with 15 side slope and 25 forward slope. The fraction removed at 0.5 A contains black ferromagnesian silicates, garnet, ilmenite, xenotime, wolframite, columbite, and some iron and manganese oxyhydroxide minerals. The fraction not removed at 0.5 A but removed at 1 A contains monazite, tourmaline, limonite, green spinel, staurolite, and polymineralic grains. The remaining nonmagnetic fraction (at the 1-A setting) contains sillimanite, kyanite, zircon, sphene, apatite, cassiterite, rutile, barite, gold, scheelite, cuprite, sphalerite, and lead and copper artifacts. The three fractions were examined by binocular microscope to determine their mineral compositions and to look for lead or copper artifacts, which, if found, were removed. The samples then were analyzed spectrographically for 31 elements.

All the spectrographic data have been entered into a computer file. The computer file contains information on possible contamination from artifacts of lead or copper, as well as analytical data.

Heavy minerals were used in the geochemical studies for several reasons. (1) Heavy minerals provide information about the geologic environment; both the chemical composition of the rocks and the degree of metamorphism can be deduced from these minerals. (2) Earlier studies had shown a greatly increased contrast between "anomalous" and "background" metal values by analyzing concentrates instead of silt and clay. (3) Industrial minerals, important products of the study area, require knowledge of the minerals present more than of the metals present, as the heavy minerals rather than a metal may be the material of economic interest (for example, kyanite). However, the barium content of the nonmagnetic fraction of concentrates also provides information about barite.

Many maps were plotted to show the distribution of metals and minerals in the Charlotte quadrangle. These are presented in 17 open-file reports (see table 1), some of which contain more than one map. Minerals and metals are shown together on a map when the particular mineral contains large amounts of the metal.

The interpretation of the geochemical data is made more complicated by the presence in the concentrates of garnet, kyanite, gold, and staurolite, particularly, which may have entered modern streams from old sediments deposited on existing hilltops and terraces before dissection of the Piedmont plateau to form the present topography. Such minerals are not related to the bedrock geology of the drainage basins in which they were collected. A regional study of the distribution of heavy minerals that are not related to the bedrock geology of the drainage basins in which they occur can provide information about early events in the sedimentary history of the region.

Three previously unsuspected geochemical features were found as a result of CUSMAP study: (1) widespread tin mineralization and associated niobium, beryllium, and other lithophyle elements; (2) cobalt associated with niobium south of Salisbury, N.C., and not associated with niobium east of Gaffney, S.C.; and (3) base-metal mineralization, consisting of zinc, lead, and cadmium, in the northeastern corner of the quadrangle. Tin has long been known in the tin-spodumene belt that passes through the town of Kings Mountain, N.C. CUSMAP studies revealed another, previously unknown, area affected by tin mineralization; this area extends westward from Kings Mountain to the western edge of the quadrangle. Mineralization containing tin, bismuth, and beryllium also extends northward beyond the previously known belt. In addition, two granite plutons, one at Brown Mountain, near the northwestern corner of the quadrangle and one a few miles south of Salisbury, N.C., are shedding tin-rich minerals into the streams that drain them. At Brown Mountain, the tin mineral is cassiterite, which is accompanied by columbite. Near Salisbury, tin is in ixiolite ($(Ta, Fe, Sn, Nb)O_2$), as well as cassiterite. Cassiterite-bearing heavy-mineral concentrates collected in the southeastern corner of the quadrangle near the Fall Line suggest that tin placers may be present near the change in stream gradients along that line.

Heavy-mineral concentrates that contain several hundred parts per million of cobalt were collected in the area south of Salisbury that yields concentrates also rich in niobium and tin. No cobalt-rich mineral has been identified in that area. An association with high manganese contents in the heavy-mineral concentrates suggests that the cobalt may be in black manganese-oxide minerals, some of which strongly scavenge cobalt. The cobalt east of Gaffney, S.C., is in an area in which concentrates also contain unusually large amounts of zinc. Iron was mined for 19th-century furnaces from at least three types of deposits, one of which was gossan. This mining provides independent evidence that the area contained sulfide minerals.

A cluster of heavy-mineral concentrates collected in the Charlotte belt near Thomasville, in the northeastern corner of the quadrangle, yielded high values for zinc, lead, cadmium, and copper. Two concentrates contained sphalerite, and two contained detectable silver. The sphalerite is pale yellow, different from the dark-brown sphalerite at the Silver Hill mine 20 km to the south in the Carolina slate belt.

MINERAL-OCCURRENCE MAPS (TABLE 1, MAP MF-1793)

About $1.1 billion of mineral production has come from the Charlotte 1°×2° quadrangle (in 1967 dollars, through 1978). About seventy-five percent of this production value has been for construction materials—stone, sand and gravel, and brick or common clay. Next in importance was spodumene (lithium), followed by mica, feldspar, kyanite, gold, iron, thorium, barite, and base metals, the last two having about $1.5 million of production each (see section on mineral production maps). A number of other less important commodities have had $200,000 to $1 million of production each—silver, pyrite, tin, and pottery clay. Location data and other information about producing or past-producing deposits (mines, quarries) and prospects for various commodities were entered in the U.S. Geological Survey's Computerized Resource Information Bank. This computer file was used to print a series of maps showing the locations in the Charlotte quadrangle of mines (quarries) and (or), for some commodities, prospects. Such maps have been prepared for (1) kyanite, sillimanite, lithium, mica, feldspar, copper, lead, and zinc; (2) gold, quartz, barite, and fluorite; (3) iron, thorium, tin, and niobium; and (4) construction materials and gemstones. These maps are useful in showing the distribution of the respective commodities relative to mapped geologic features and to geochemical data.

MINERAL-RESOURCE POTENTIAL MAPS (TABLE 1, MAPS I-1251-G TO M)

Different types of data assembled during CUSMAP studies and pertaining to 14 commodities or groups of commodities have been combined wherever feasible to derive maps of resource potential for the different commodities. The types of information on which these maps are based are (1) the occurrence of appropriate minerals (mineralization) as shown by the presence of mines or prospects; (2) the presence of appropriate geochemical anomalies, applicable principally to metallic minerals; (3) the presence of appropriate heavy-mineral anomalies; and (4) the identification of a favorable geologic formation (host rock), group of formations, or other geologic feature such as an alluvial deposit. The identification of a favorable geologic formation or other feature requires a distinct association of any of the first three of these factors with a geologic formation, group of formations, or other geologic feature. Most of the mineral-resource potential maps locate and represent in color a unit or units favorable for resources. The colors correspond to those used in the geologic map of the quadrangle (map I–1251–E). The unit portrayed may be a single formation on the geologic map or some combination of adjacent formations or parts of formations.

Positive indications of resource potential are designated on most of the maps as "high," "moderate," or "low," while intervening areas are assumed to have, or are labeled as having, no potential or no evident potential. The presence of a favorable geologic unit for a specific commodity is sufficient to delineate a zone of low resource potential for the commodity being considered. High potential generally is deduced for the combination of appropriate mineral occurrence and a favorable geologic unit or host rock, and moderate potential is inferred where a geochemical and (or) heavy-mineral anomaly occurs within a favorable geologic unit. Low potential is inferred when factor 1, 2, or 3 occurs alone; that is, not in combination with any of the other factors (fig. 2). Geophysical anomalies alone have not been used directly in the Charlotte quadrangle in determining mineral-resource potential, but anomalies have been of indirect importance in helping determine the areas underlain by certain geologic units, particularly plutons. Data available for some commodities may not be suitable for determination of high, moderate, or low potential according to the above scheme; areas of potential resources of such commodities may be labeled on corresponding maps simply as "areas having resource potential" or "areas broadly favorable" for resources.

Separate maps show resource potential for copper, lead, zinc, and combined base metals; gold; tin and tungsten; beryllium, molybdenum, and niobium; lithium, kyanite-sillimanite, and barite;

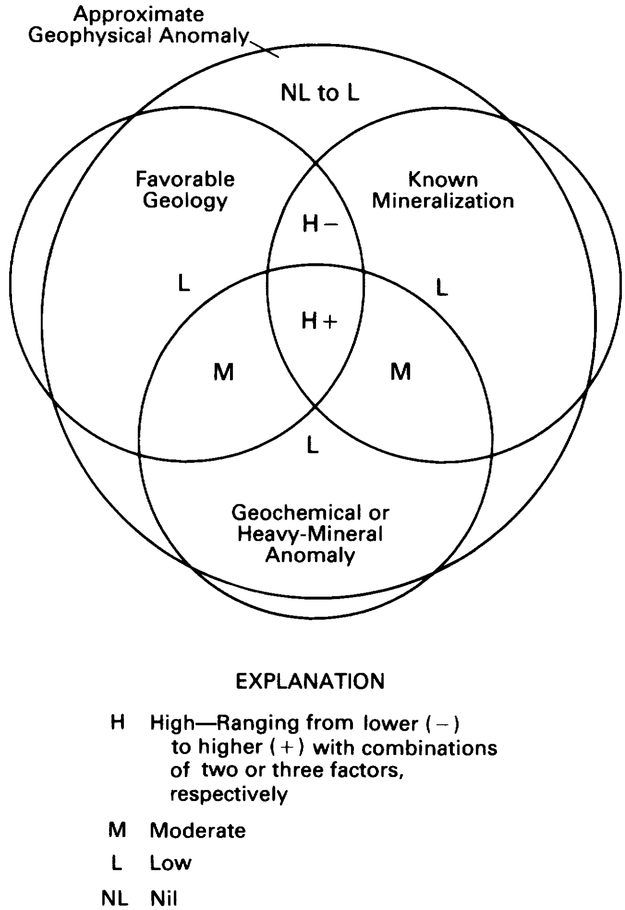

FIGURE 2.—Schematic diagram for estimating mineral-resource potential.

thorium (monazite) and uranium; and construction materials (crushed stone and sand, gravel, and clay). Each map contains an explanation of resource potential for that map or shows what combinations of specific data are used to determine degrees of resource potential.

In assessing the potential for stone resources, formations or types of rock that have been quarried are arbitrarily assigned high potential. Low to nil potential is assigned to those formations or types of rock most dissimilar to the high-potential rocks in physical characteristics such as strength, resistance to weathering, and fissility (map I–1251–M, sheet 1).

The resource-potential maps for individual commodity elements show sample sites at which anomalously high concentrations of the elements being considered occur. Some maps also show the locations of concentrations of other trace elements that are commonly associated with a given commodity element. For example, the resource-potential maps for copper, lead, and zinc show concentrations of one or both of the other base metals, and the map for tin shows concentrations of beryllium, niobium, and tungsten. Concentrations of such associated elements are not necessarily used to define a formal level of resource potential such as high, moderate, or low for the principal element but are included on such maps as supplementary data that might help some map users to estimate a degree of potential between or less than the formal categories.

For a few of the mineral-resource potential maps, designations of resource potential are based in part on concentrations of appropriate heavy minerals. Thus, locations where particulate gold is visible in pan concentrates help to define areas of resource potential on the gold maps (map I-1251-H); cassiterite occurrences help to define areas of tin potential on the tin-tungsten map (map I-1251-I), and, on the same map, scheelite concentrations help identify areas of tungsten potential. Areas of monazite concentration (past production) help to define areas of thorium potential on the thorium map (map I-1251-L), and sphalerite occurrences help define areas of zinc or lead potential on the zinc and lead maps (map I-1251-G, sheets 1 and 2). The zinc map (I-1251-G, sheet 2) also shows sites that contain zincian spinel and staurolite, some of which is rich in zinc. The areas of resource potential shown for zinc have not been defined by using the latter two zinc-bearing minerals because their usefulness in signifying a potential for zinc resources has not been determined. They probably reflect a higher-than-normal geologic background content of zinc in the areas where they occur, and so the locations of these zincian minerals are shown to direct attention to areas possibly having potential zinc resources.

The mineral-resource potential maps for lead-zinc, tin-tungsten, beryllium-molybednum-niobium, and thorium-uranium contain data from the National Uranium Resource Evaluation (NURE) for the area of the Charlotte quadrangle (Heffner and Ferguson, 1978; Ferguson, 1979). The data were obtained from samples of fine-grained alluvium (minus 100 mesh) or well water (for uranium) and are not directly comparable with the CUSMAP data from pan-concentrate samples. Trace-element abundances in the NURE samples are commonly one or more orders of magnitude less than abundances of the same trace element in the CUSMAP samples, and anomalies shown by the NURE data generally correspond only very broadly with anomalies from CUSMAP data or with favorable geologic units identified by CUSMAP data. The NURE data are used to deduce mineral-resource potential only on the thorium and uranium maps because CUSMAP data for such determinations were insufficient. However, the NURE data are shown on the other mineral-resource potential maps to provide supplementary information to explorationists.

MINERAL-PRODUCTION MAPS (TABLE 1, MAP I-1251-F, SHEETS 1-3)

The mineral-production maps show the distribution of quantity and value of reported past production of mineral commodities through 1978 from counties that are entirely or partially within the boundaries of the Charlotte quadrangle. There are 31 such counties, 27 of the 100 counties of North Carolina and 4 of the 46 counties of South Carolina. Most of the production data used in the preparation of these maps were collected during the annual canvasses of mineral producers conducted by the U.S. Bureau of Mines (since 1924) and by the U.S. Geological Survey (1882-1923). Additional sources used for production data include U.S. Bureau of the Mint reports for precious metals and the Economic Paper series of the State of North Carolina. County data are not available for all mineral commodities for identical time spans; county precious-metal data were obtained for years since 1880, and data for other commodities were gathered for years since about 1900.

The unit regional value approach of J. C. Griffiths (1978) was used to calculate cumulative totals (physical measures in equivalent metric units; values in 1967-constant U.S. dollars). Therefore, the mineral-commodity classification used in J. C. Griffiths' computer programs was closely adhered to. This classification system groups all known mineral commodity names into a list of 77 standard mineral commodities. These commodities are further classified into the following five commodity categories: construction materials, fuels, metals (not including gold and silver), nonmetallic minerals, and precious metals and materials.

Calculated results for cumulative quantity and value, as well as for cumulative quantity and value per unit area, are displayed on the maps. The maps highlight the importance of stone (crushed and dimension) and sand and gravel production. These commodities account for 54 and 12 percent, respectively, of the constant dollar value of reported production of all mineral raw materials in the 31 Charlotte counties; together these two commodities account for 88 percent of the construction materials category, which, in turn, accounts for 75 percent of all commodities. The total value of production by commodity category for each county is shown on the maps. Crushed and dimension stone contribute more than 80 percent of the cumulative constant dollar value of 5 of the leading 10 counties, and sand and gravel constitute 97 percent of another county's value. Cleveland County, a producer of stone and lithium minerals, leads the 31 counties in value of cumulative mineral production (in 1967 dollars) with $160 million; it ranks second in value per unit area (unit regional value), with $132,000/km^2. Polk County has the smallest total production ($3.37 million) and ranks 29th in unit regional value with $5,440/km^2; 98 percent of this production value is for construction materials. Several county totals include production of material for parts of those counties that are outside the boundaries of the Charlotte quadrangle. Mitchell County, which ranks second in total production value ($145 million) and first in unit regional value ($260,000/km^2), owes much of its cumulative value to feldspar and mica produced outside of the quadrangle. Anson County's totals ($94.1 million, ranked fourth, and $68,200/km^2, ranked third) are almost entirely attributable to sand and gravel production from deposits outside the quadrangle boundaries. Caution must be used in comparing values of commodities because the reported value is based on selling price and thus includes production costs of labor, transportation, and returns to capital, as well as economic rents attributable to the mineral resource.

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