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Geophysical and Geologic Studies in Southern Mecklenburg County and Vicinity, North Carolina and South Carolina

By Frederick Albert Wilson

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GEOPHYSICAL AND GEOLOGIC STUDIES IN SOUTHERN MECKLENBURG COUNTY AND VICINITY NORTH CAROLINA AND SOUTH CAROLINA

By

Frederick Albert Wilson

B.A. September 1966, Brooklyn College of the

City University of New York

M.A. January 1970, Brooklyn College of the

City University of New York

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John Frederick Lewis

Professor of Geology

ABSTRACT

Geophysical methods consisting of gravity, aeromagnetics and aeroradioactivity have been applied to part of the Charlotte and Carolina slate belts in southern Mecklenburg County and vicinity to help interpret geology, lithology and structure. High aeroradioactivity is associated with potassium-rich granitic plutons, muscovite-rich gneisses, schists, and metavolcanic rocks; positive gravity and magnetic anomalies are associated with gabbro plutons; and negative gravity anomalies are associated with granitic plutons.

At the west side of the slate belt, the Tillery phyllite is interpreted as having undergone progressive metamorphism. The underlying Uwharrie Formation extends into the Charlotte belt where it is mapped as metavolcanic rocks. Gravity models of the Carolina slate belt indicate that it is a synform containing a wedge of metasedimentary and volcanoclastic rock on plutonic basement. The basement is exposed in the adjacent Charlotte belt antiform.

The northern Charlotte belt contains mainly plutonic rocks which have been divided into 3 supergroups of plutons based upon chemistry, mineralogy, texture, and age. They are:

1. Old Plutonic supergroup - plutons 545-490 m.y. that are medium to coarse-grained tonalite, quartz diorite, and granodiorites.

2. Concord-Salisbury supergroup -- plutons 426-350 m.y. which form sheet-like intrusions of differentiated gabbro; local volcanic centers

with ring complexes 13 km in diameter that suggest magma chambers 0 - 8 km deep; smaller bodies of diorite, monzonite, and syenite; and small Salisbury type granodiorites.

3. Landis supergroup -- plutons 350-280 m.y. that are usually very coarse-grained, porphyritic, "big feldspar," potassium-rich granites.

The Mecklenburg-Weddington gabbro complex of the Concord-Salisbury supergroup, the largest feature in the study area, contains three large gabbro plutons. The gabbro intruded Old Plutonic complex rocks and could have produced the metamorphic reaction K-feldspar + sillimanite = quartz + muscovite reflected in the mineral assemblage of adjacent felsic metavolcanic rocks. Gravity models indicate a lopolith 3.5 to 4.5 km thick with a 2 km sill extending to the northeast. Positive magnetic and gravity anomalies suggest the lopolith is connected with the Concord gabbro complex to the northeast.

The sheet-like intrusions of Concord-Salisbury group gabbros, forming the core of the composite batholith, have medium-grained Salisbury type granodiorite above, and coarser-grained Landis granite below. The position of the supergroups as presently exposed may be a function of level of erosion versus level of emplacement.

The plutons in the composite batholith span 200 m.y. according to current age data and are arranged with the oldest at the top and the youngest at the bottom. However, Rb-Sr and K-Ar ages in the Piedmont are more likely to reflect age of crustal uplift than the age of metamorphism or intrusion. The Charlotte belt composite batholith, therefore, may very well be the result of a shorter single tectonic event or process.

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INTRODUCTION

Purpose of study

The purpose of the study is to map and interpret the geology of 10 quadrangles of the Carolina Piedmont (fig. 1) south of Charlotte, N.C. in southern Mecklenburg County and vicinity (fig. 2). The study has employed methods of gravity, aeromagnetics, and aeroradioactivity to help overcome the severe problem of lack of fresh rock exposures and to identify and trace rock units[1] covered by saprolite.

The Appalachian Piedmont (fig. 1) is a band of Precambrian to early Paleozoic variably deformed and metamorphosed rock that stretches from Alabama to New Jersey in the southeastern United States. This province was America's first source of economically important minerals such as gold, iron, silver, copper, barite, manganese, corundum, and presently is "the most important source of lithium in the world today" (Kunasz, 1976, p. 27).

The Piedmont is in part covered by Cretaceous coastal plain sediments and occupies an important structural position between the uplifted Precambrian core of the Appalachian Blue Ridge, and the Atlantic Ocean basin. A knowledge of this area is, therefore, required before any interpretations can be made and realistic plate tectonic models formulated of the Appalachian orogen.

Fisher described the Piedmont as the least understood, yet one

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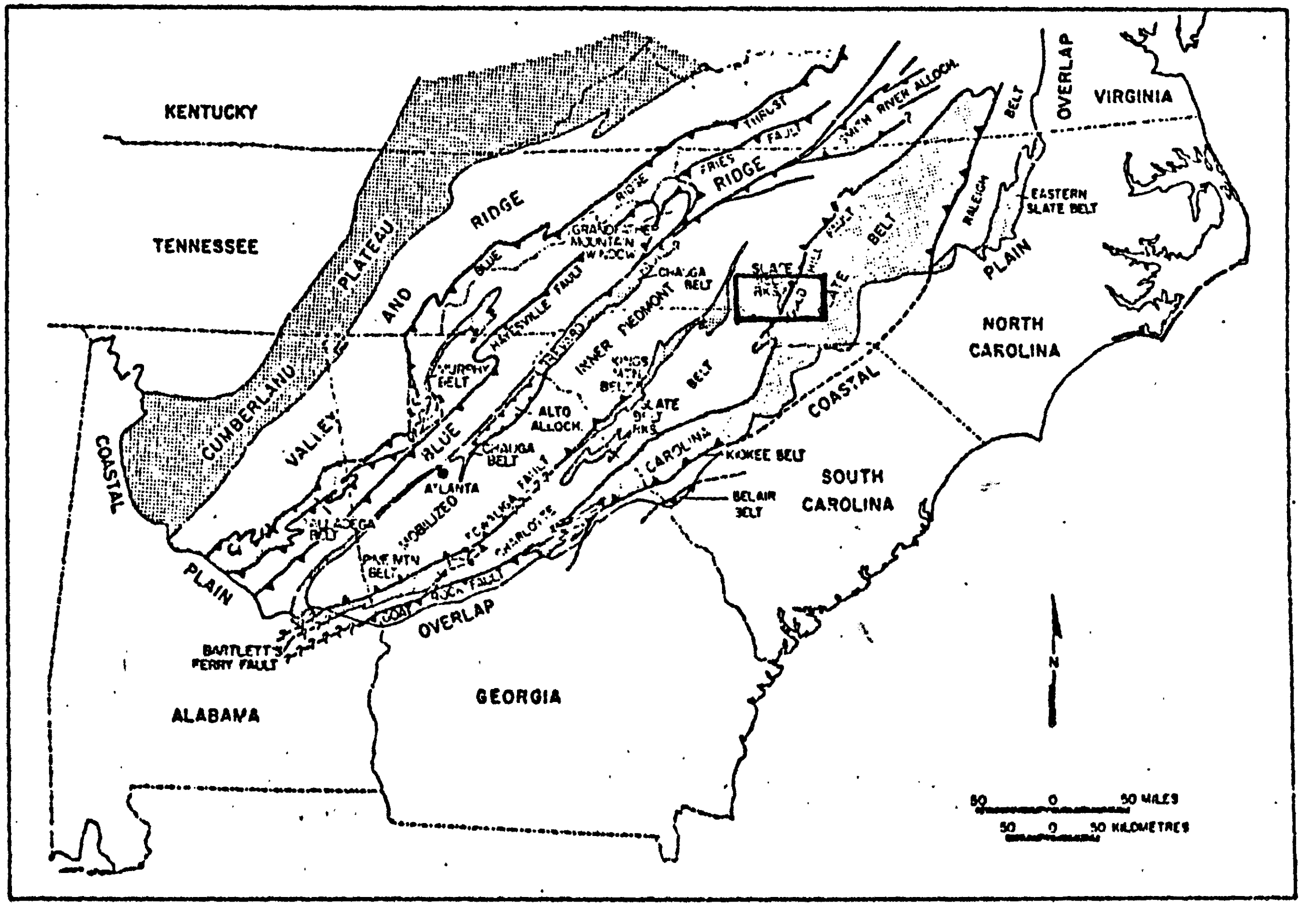
[1]Many names used in this paper for geologic and geophysical features are informal and are introduced by the author for the purpose of clarity.

Figure 1. Map showing major subdivisions of the southern Appalachians including the Piedmont belts (Hatcher and Butler, 1979). Study area in bold black lines.


KENTUCKY
TENNESSEE
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
ALABAMA
CUMBERLAND PLATEAU
VALLEY AND RIDGE
BLUE RIDGE
INNER PIEDMONT
COASTAL PLAIN OVERLAP
EASTERN SLATE BELT
RALEIGH BELT
CAROLINA SLATE BELT
CHAUGA BELT
ALTO ALLOCH.
MURPHY BELT
HAYESVILLE FAULT
GRANDFATHER MOUNTAIN WINDOW
FRIES FAULT
THRUST FAULT
SMITH RIVER ALLOCH.
KINGS MTN BELT
KIOKEE BELT
BELAIR BELT
ATLANTA
PINE MTN BELT
GOAT ROCK FAULT
BARTLETT'S FERRY FAULT
N
50 0 50 MILES
50 0 50 KILOMETRES

of the most fascinating parts of the Appalachians (Fisher, 1970, p. 295). Piedmont geology is little understood for several reasons: (a) exposures of unweathered bedrock are rare; (b) in most of the Piedmont, the bedrock is covered by deep residual soils and a thick mantle of saprolite - a soft material formed from thoroughly decomposed chemically weathered rock; (c) distinct widespread stratigraphic units have not been identified in many areas, and only two fossil occurrences have been reported within the Piedmont (St. Jean, 1965, Spanjers and Aldrich, 1979, Tull, Neathery and Sutley, 1979); and (d) structural interpretations are difficult in some areas because of multiple deformation and metamorphic changes. Unfortunately in the Charlotte belt, where plutonic intrusions are common, there are few helpful structural features which can be used to understand the relationships between units.

Description of the study area

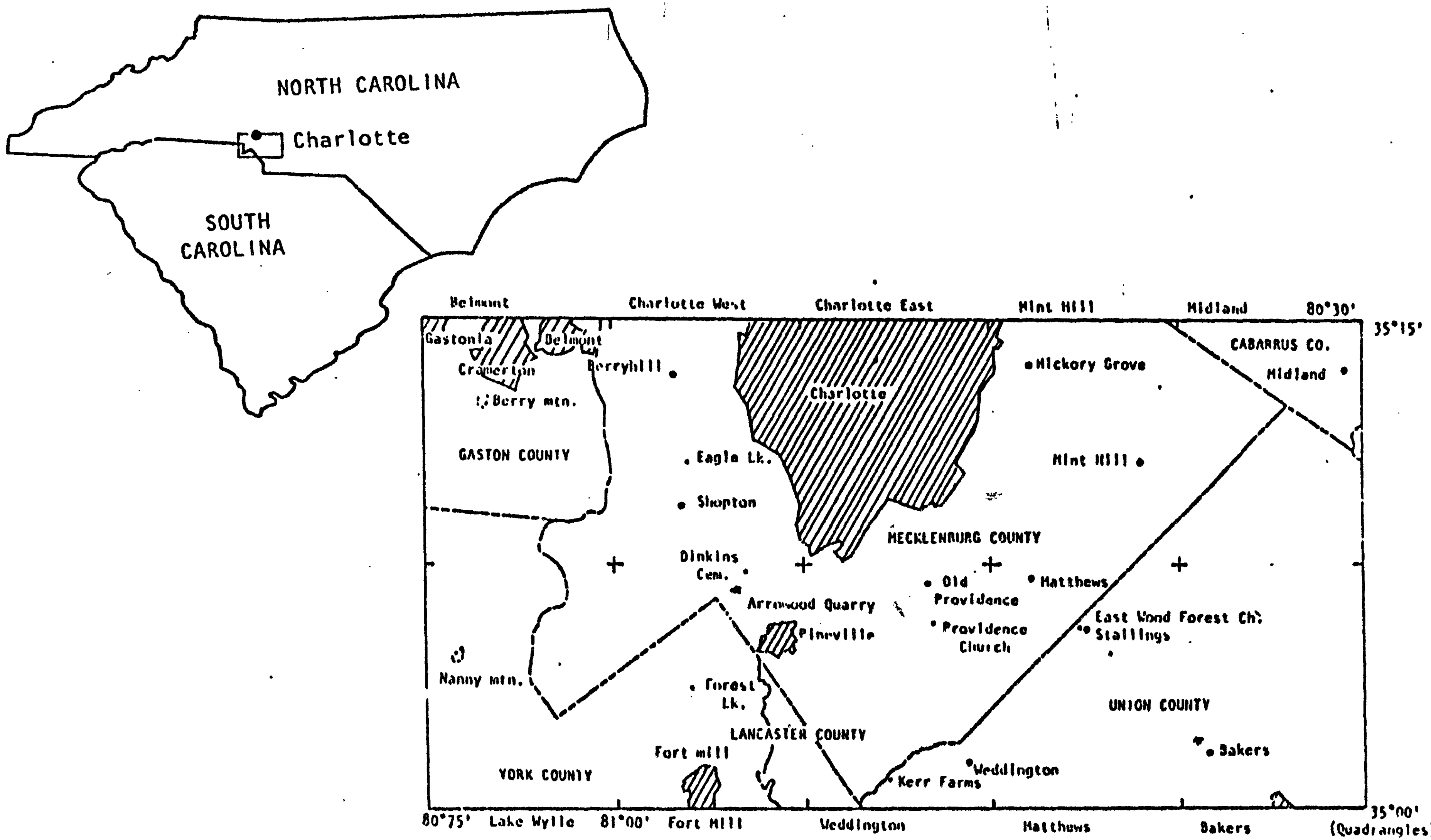
Location

The study area is located south of the center of Charlotte, North Carolina (fig. 2). It is bounded by latitudes 35°00′ to 35°15′N, and longitudes 80°30′ to 81°7.5′W; its dimensions are 27 km (17 miles) north to south, and 57 km (35 miles) east to west; and it contains 1556 square km (605 sq. miles). The U.S. Geological Survey 7.5′ quadrangle topographic maps of the area are Baker, Belmont, Charlotte East, Charlotte West, Matthews, Midland, Mint Hill, Weddington, Fort Mill and Lake Wylie (fig. 2).

Culture

Most of southern Mecklenburg County and adjoining parts of Union, Gaston, Cabarrus, and Stanley Counties, N.C.; and Lancaster and York

Figure 2. Index and cultural map of southern Mecklenburg County and vicinity, North Carolina and South Carolina.


NORTH CAROLINA
Charlotte
SOUTH CAROLINA
Belmont
Charlotte West
Charlotte East
Mint Hill
Midland
80°30'
35°15'
Gastonia
Belmont
Cramerton
Berry mtn.
Berryhill
Charlotte
Hickory Grove
CABARRUS CO.
Midland
GASTON COUNTY
Eagle Lk.
Shopton
Mint Hill
MECKLENBURG COUNTY
Dinkins Cem.
Arrowood Quarry
Old Providence
Matthews
Pineville
Providence Church
East Wood Forest Ch.
Stallings
Nanny mtn.
Forest Lk.
UNION COUNTY
LANCASTER COUNTY
Fort mill
YORK COUNTY
Weddington
Kerr Farms
Bakers
80°75'
Lake Wylie
81°00'
Fort Mill
Weddington
Matthews
Bakers
35°00'
(Quadrangles)

Counties, S.C., are included in the mapped area (fig. 2). The city of Charlotte and its suburbs occupy the north-central part of the study area. Other municipalities which are partially, or totally, within the area, are Belmont, Gastonia, Cramerton, Monroe, Pineville, Hickory Grove, Wilgrove, Mint Hill, Indian Trail, and Weddington, in North Carolina, and Fort Mill, South Carolina.

Topography

The topography is that of a gently rolling Piedmont plain which slopes to the east, and southeast. It consists of broad divides between incised streams. The highest elevations are found west of Lake Wylie, on top of Nanny Mountain 293 m (960′), and about one mile south of Cramerton on Berry Mountain 282 m (925′) (see fig. 2). The lowest elevation is located where Goose Creek flows into the Rocky River at the northeastern edge of the area south of the intersection of the Cabarrus, Union, and Stanley County boundaries. Although these elevatons give a maximum relief of 155 m (510′), most of the area lies between 213 m (700′) and 183 m (600′) above sea level, except for the incised stream valleys and the mountainous ridges in the extreme west.

The Catawba River, the largest stream, flows south through the western part of the area. This river is dammed west of Fort Mill to produce electrical power, and its impounded water forms Lake Wylie. The Catawba River and its tributaries (Steel, Sugar, Little Sugar, McAlpine, McMullen, and Four Mile creeks) drain the western central, and southeastern portions of the area; and the Rocky River and its tributaries (Goose, Duck, Crooked, and Stewart′s creeks) drain the northeastern corner of the area. The two drainage systems are separated by a broad dissected ridge which extends from Hickory Grove to Monroe.

Geologic setting

The study area encompasses part of the Charlotte and Slate belts (fig. 1) which are two of the five Piedmont lithotectonic belts of the southern Appalachians described by Hatcher (1972). The rock types exposed within the Charlotte belt include amphibolite facies schists, gneisses, metavolcanic rocks and granitic to gabbroic plutons which range in age from 545 to 280 m.y. (Fullagar, in press). The boundary with the Slate belt to the east is distinct and may be faulted in places. The Slate belt contains gently folded volcanoclastic and epiclastic metasedimentary rocks of greenschist facies that are cut by quartz veins and intruded by metagabbro dikes and sills. Quartzite and sericite schists, similar to quartzites and schists in the adjoining Kings Mountain belt, commonly occur in the western part of the study area.

The principal geologic features of the study area are:

(1) The Gold Hill-Silver Hill fault system which is thought to form the sharp border between the Charlotte belt and Carolina slate belt.

(2) The Mecklenburg and Weddington gabbros, Weddington granite, and Stallings granodiorite which are the largest plutons in the area. These plutons crop out in close proximity to each other, suggesting a structural or genetic relationship.

Previous work

Three of the units described by Kerr (1882) are found in the study area. Kerr's map units are Huronian Slate (Carolina slate belt), Granite (Charlotte belt), and Huronian slate (Kings Mountain belt). The granite-slate (Charlotte-Carolina slate belt) boundary shown on Kerr's map is so distinct in this area that it is almost unchanged on present-day maps. However, on Kerr's map, the King's Mountain belt rocks are shown as occupying most of the area west of the Catawba River, an area now regarded by most geologists as part of the Charlotte belt. Although the Charlotte belt is shown as granite on Kerr's map, it is described in his report as also containing mafic plutons and metavolcanic rocks (Kerr, 1875). Kerr assigned the same Laurentian age to the King's Mountain and Slate belt rocks and proposed that they were possibly derived from the higher grade metamorphic and plutonic rocks of the Charlotte and Raleigh belts.

Le Grande and Mundorff (1952) remapped the Charlotte area in greater detail, using reconnaissance mapping and information from water wells. They selected map units based upon the predominance of granite, diorite or gabbro and called attention to the proximity of these rocks in time and space. The map of Mecklenburg County, by Le Grande and Mundorff (1952, p. 47) shows a unit of gabbro-diorite in the area occupied by the present Mecklenburg gabbro complex (Hermes, 1968), and of Weddington gabbro (Butler, 1978; Goldsmith and others, 1978). The map of Gaston County shows units containing mica schist along with the plutonic units.

King (1955) described and proposed names for the Appalachian belts. The cross section of his map passes through the study area and his interpretation is similar to that of Kerr (1882). Stuckey and Conrad (1958) used a more generalized version of LeGrande and Mundorff's map in the compilation for the Geologic map of North Carolina.

The geologic map of the crystalline rocks of South Carolina, by Overstreet and Bell (1965b), shows the York County part of the study area as occupied by biotite gneiss and occasional bodies of sericite schists and by swarms of mafic dikes. Overstreet and Bell (1965b) also show argillite and muscovite schist in Lancaster County and in the southern part of the Mecklenburg gabbro complex at the state boundary with North Carolina. This map is largely based on soil maps and on the concept that there are stratigraphic correlations between Slate belt rocks and King's Mountain belt rocks (Overstreet, 1970, Overstreet and Bell, 1965a, p. 8-16).

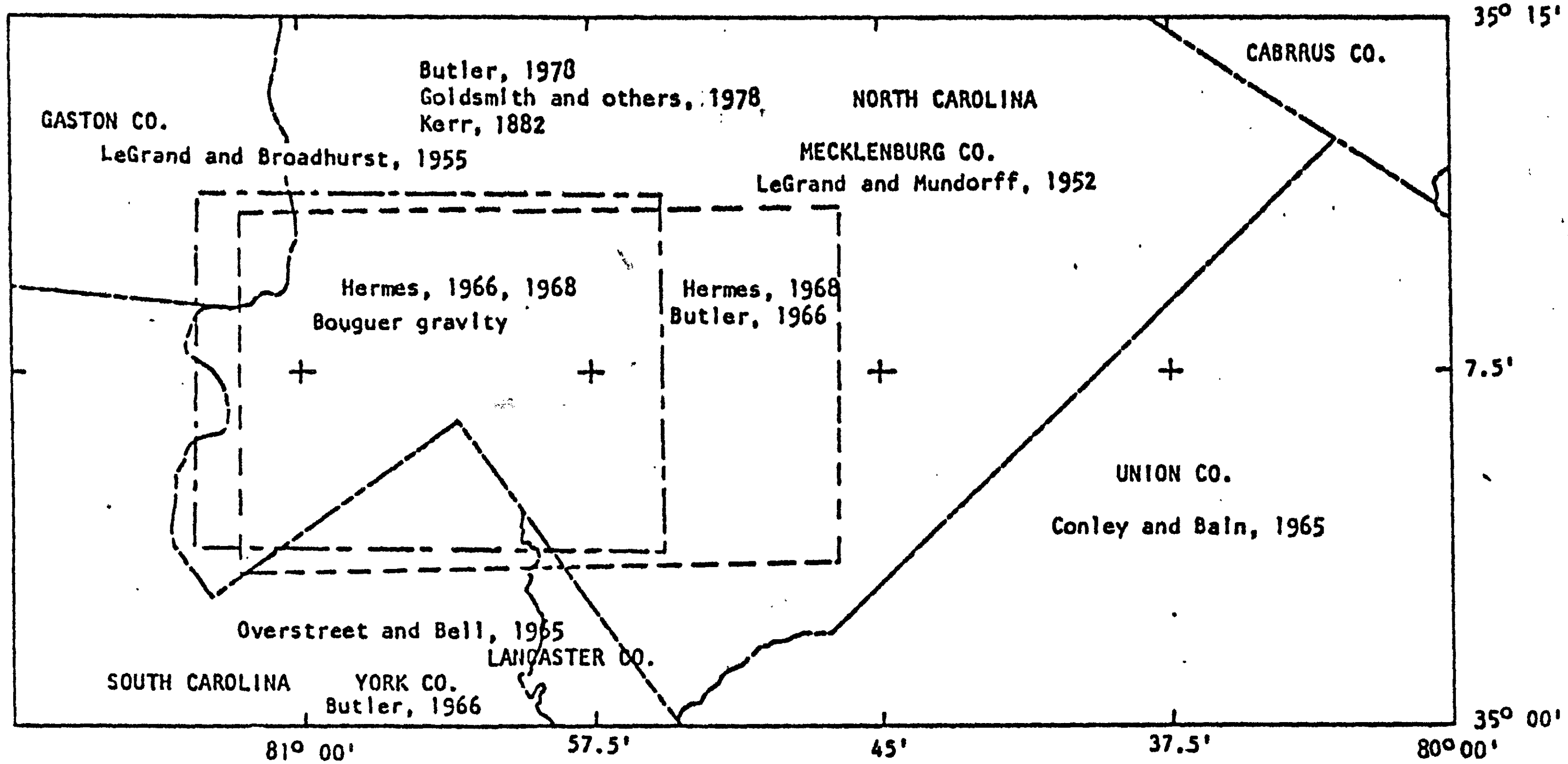
On the geologic map of York County, South Carolina, Butler (1966) shows the mica gneiss of Overstreet and Bell as adamellite and diorite tonalite. Butler also shows the biotite gneiss as located directly south of the Mecklenburg gabbro complex, and remapped many of LeGrand and Mundorff's diorite and granite units, west of the Catawba River as diorite-tonalite. The generalized gabbro-diorite is shown as two amphibolite units, and the granite and mica schist as foliated adamellite and two phyllite units.

The composite geologic map of the Carolina Slate belt in North Carolina, west of the Deep River-Wadesboro Triassic Basin (Conley and Bain (1965), covers the southeastern corner of the study area. Except for a single area of granite at the border of Mecklenburg County, this map shows a normal stratigraphic sequence from the Uwharrie Formation to the Yadkin Formation in the core of the New London syncline in Midland quadrangle. No faults are shown on the Conley and Bain map in this area, but the Yadkin Formation and the New London syncline are truncated and juxtaposed with the Tillery Formation along the trace of the Silver Hill fault (Stuckey and Conrad, 1958; Butler, 1978; Goldsmith and others, 1978).

Hermes (1968) made a petrologic and gravity study of the Mecklenburg gabbro complex which is made up of gabbro and hornblende gabbro. He concluded that the Mecklenburg gabbro had intruded an

Fig. 3. Index map of the study area showing contributions to geologic mapping.

Butler, 1978..............................Charlotte 2° Sheet
Butler, 1966..............................York County
Conley and Bain, 1965.....................Union and Cabarrus Counties
Goldsmith and others, 1978................Charlotte 2° Sheet
LeGrand and Mundorff, 1952................Gaston and Mecklenburg Counties
LeGrand and Broadhurst, 1955..............Mecklenburg County
Overstreet and Bell, 1965.................South Carolina



earlier regionally metamorphosed gabbro. His gravity study showed that the thickness of the western part of the complex was a minimum of 2,590 m (8,500 feet) and could possibly be as much as 6,096 m (20,000 feet).

Butler's (1978) reconnaissance map of the Charlotte 2° sheet added the gabbro body west of Weddington, a large granite body along the slate belt in southern Mecklenburg County, and three major faults along the Carolina slate belt-Charlotte belt boundary. Later reconnaissance mapping, largely by Milton (Goldsmith and others, 1978), has added gneiss units, subdivided the granite unit of Butler (1978), and retained only the Silver Hill fault, in the Carolina slate belt.

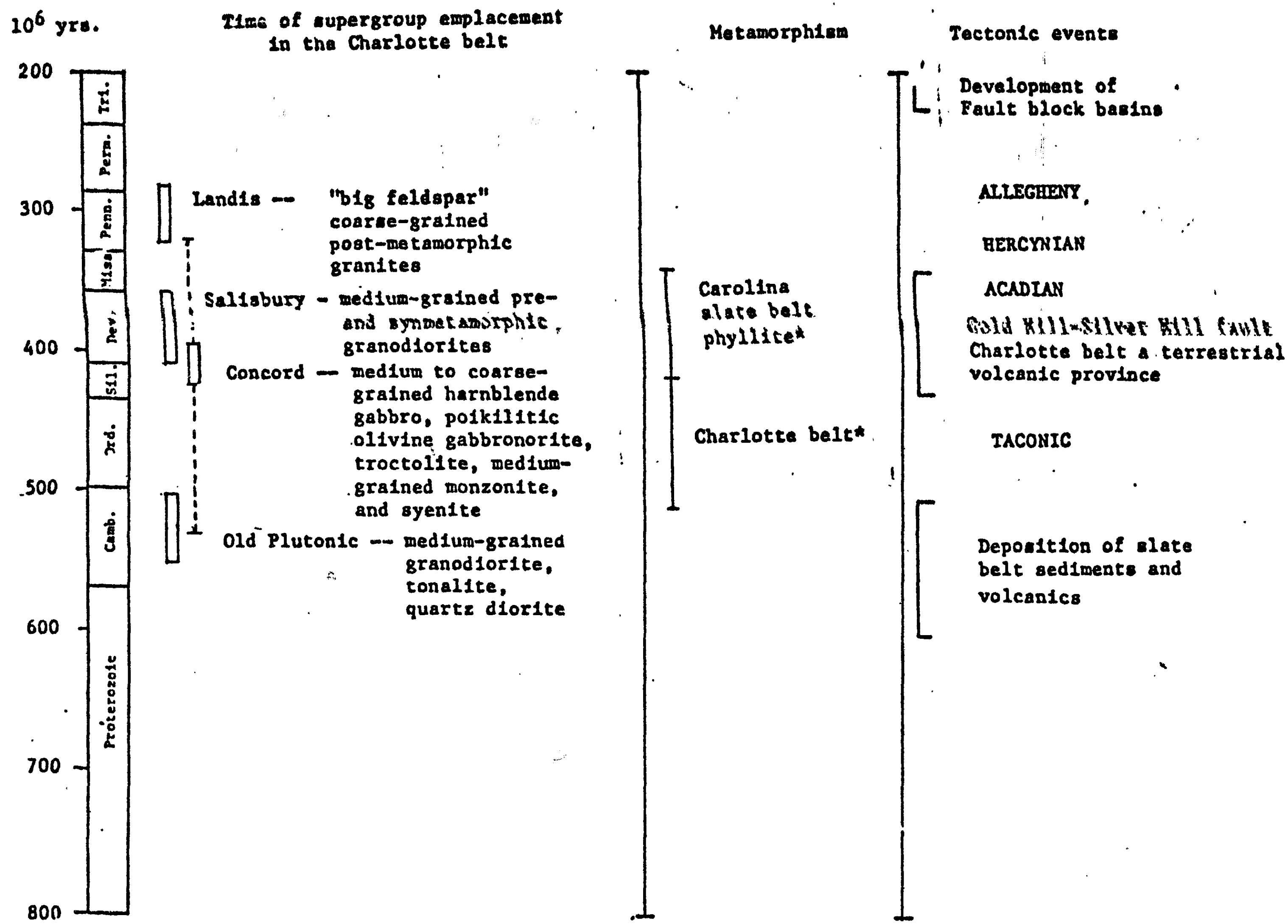
GEOLOGY

Introduction

Most geologic studies in the Charlotte belt have been confined to chronological, geochemical, and petrologic studies of plutons. These studies have grouped plutons according to chemistry, mineralogy, and by their relationship to the time of regional metamorphism, which occurred between 413-365 m.y., and 320-280 m.y. (Butler and Ragland, 1969). Dating of Charlotte belt plutons indicates 3 significant periods of igneous activity: 545-490 m.y., 415-390 m.y., 320-280 m.y. (Fullagar, 1980 in press) (fig. 4). These groups of ages lie within the span of the Cambrian (570-500 m.y.), Devonian (415-360 m.y.), and Pennsylvanian-Mississippian (360-290 m.y.) tectonic and intrusive events. These age relationships have led most geologists working in the Piedmont to relate plutonic intrusions to the major period-forming events and to classify plutons as pre-metamorphic, syn-metamorphic, or post-metamorphic.

Regional metamorphism began about 413 m.y. (Butler and Ragland, 1969) after emplacement of the Salisbury pluton at the eastern edge of the Charlotte belt. Emplacement of the Salisbury pluton was preceded by intrusion of the Concord and Mecklenburg-Weddington gabbros at about 425 m.y. (Overstreet and Bell, 1965a). Metamorphism was accompanied by folding of Carolina slate belt rocks and faulting along the Charlotte - Carolina slate belt border, producing the Gold Hill and Silver Hill fault. This dynamothermal metamorphism produced little deformation of the older Charlotte belt plutons. This suggests that regional metamorphism may have occurred earlier in the Charlotte belt than in the Slate belt, possibly before the intrusion of the Concord and

Figure 4. Diagram showing time-relationship between plutonism, metamorphism, and tectonic history in the northern Charlotte belt.



*Butler and Fullagar (1978, p. 465)

Mecklenburg-Weddington gabbros, and possibly during the regional metamorphism of the Inner Piedmont and Blue Ridge, 480-430 m.y. (Butler, 1972).

Another interpretation of these magma groups is that they are part of the normal development of a composite batholith similar to the development of the Coastal Batholith of Peru described by Pitcher (1978), Cobbing and others (1977), and Cobbing and Pitcher (1972). The Coastal Batholith is 120 km long and is composed of hundreds of plutons which represent discrete pulses of magma. The plutons are divided into units which are identified by age, composition, texture, fabric, and structural position in the batholith. Supergroups are temporal and spatially associated plutonic units which have a "basic to acid" magma sequence or "rhythm." Regardless of the mechanism employed to generate batholithic plutons, some unvented magmas must remain at depth after the batholith-forming process has stopped, producing a batholith stratigraphy and structure.

The names of the rock units of the study area (Plate 1, 2) are from Goldsmith and others (1980); the descriptions and areal distribution are based upon gravity, radioactivity, and magnetic data, reconnaissance mapping, and collected rock samples. Carolina slate belt stratigraphy is based on the work of Conley and Bain (1966) and Conley (1962).

Carolina slate belt

The stratigraphy of the slate belt was defined by Conley (1962) and was subsequently revised in 1969 (Seiders, 1978, p. 245) (fig. 5). The oldest stratigraphic unit is the Uwharrie Formation of Late Precambrian or Cambrian age which is composed mainly of felsic volcanic rocks. The Uwharrie Formation is overlain by the Albemarle Group — 3 formations of Early Paleozoic or Cambrian age. The basal unit of the group is the

Tillery Formation, mainly thin bedded mudstone; the middle unit, the Cid Formation, contains a lower Mudstone Member and an upper Flat Swamp Member of volcanic rock; and the upper unit, the Millingport Formation, contains a lower Floyd Church Member of mudstone, and an upper Yadkin Member of volcanic rock. The latest geologic mapping in the area (Goldsmith and others, 1978) shows Cambrian rocks of the lower Mudstone Member and the upper Flat Swamp Member of the Cid Formation and the Floyd Church member of the Millingport Formation of undetermined age, east of the Silver Hill fault. An unassigned phyllite unit lies west of the fault along the border of the Charlotte belt and a metavolcanic unit extends into the Charlotte belt. These units are respectively assigned to the Tillery and Uwharrie Formations.

Millingport Formation

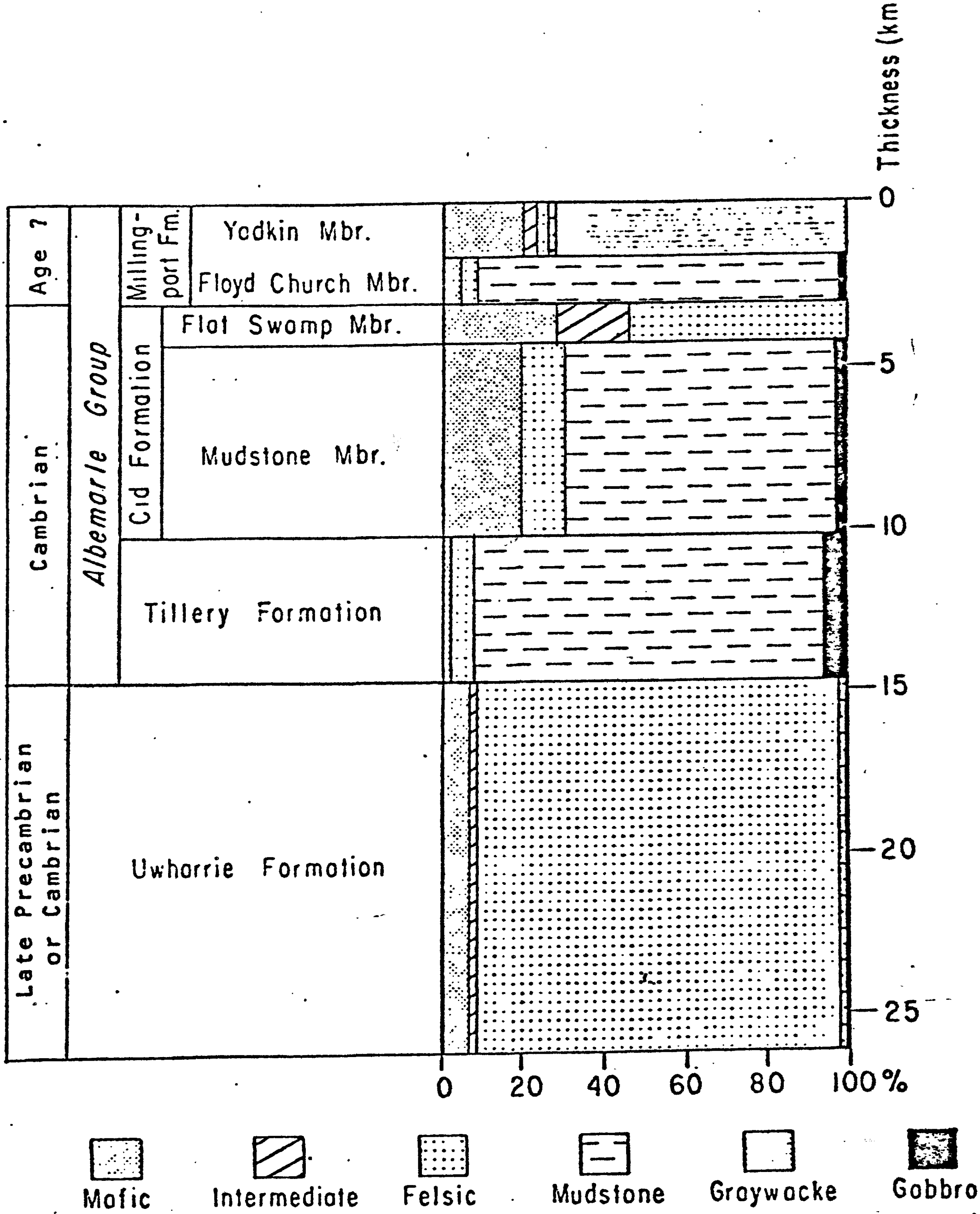
Rocks of the Floyd Church member (Cmf) of the Millingport Formation occupy the nose of the New London syncline which extends into southeastern Midland quadrangle (Goldsmith and others, 1978). The Floyd Church member is mainly a metamudstone, about 1.4 km thick, and the most likely source of the Cambrian trilobite described by St. Jean (1973, p. 202, Seiders, 1978, p. 250). A weathered sample of this formation was obtained from exposures along road 1601, Midland quadrangle, where the maroon and vermillion colored saprolite described by Conley (1962, p. 7) can be seen.

Cid Formation

Most of the eastern part of Bakers quadrangle is occupied by the lower mudstone member of the Cid Formation (Cc) which was formerly mapped as the McManus Formation by Conley and Bain (1965, p. 127). They described it as thin bedded argillaceous tuff that weathers to dark

Figure 5. Stratigraphy of the Carolina slate belt of central North Carolina after Sieders and Wright (1977).

15a



Thickness (km)
0
5
10
15
20
25
Age ?
Cambrian
Late Precambrian or Cambrian
Albemarle Group
Milling-port Fm.
Yadkin Mbr.
Floyd Church Mbr.
Cid Formation
Flat Swamp Mbr.
Mudstone Mbr.
Tillery Formation
Uwharrie Formation
0
20
40
60
80
100%
Mafic
Intermediate
Felsic
Mudstone
Graywacke
Gabbro

shades of brown. In addition to the argillite, the formation contains beds of mafic and felsic tuffs and lenticular masses of calcite.

The Flat Swamp member (Ccfs) of the Cid Formation is one such volcanic unit of mainly light to dark gray, fine grained to aphanitic, massive felsic tuff which weathers chalky white and forms an excellent marker horizon (Conley, 1965, p. 128). Seiders and Wright (1977, p. 8) describe the Flat Swamp member as pinching out in the Albemarle quadrangle and the lower mudstone member continuing to the south. Mapping by Milton (Goldsmith and others, 1978) continued both members south and around the nose of the New London syncline (Conley and Bain, 1965, p. 128).

Seiders (1978, p. 25) reports that the mudstone member attains a thickness of about 6 km (20,000 feet) and the Flat Swamp member about 1.2 km (4000 feet). Exposures of the mudstone in the study area are best seen in the Bakers Quarry, 0.6 km northwest of Bakers and about 12 km northwest of Monroe, N.C. Three samples of mudstone were obtained: fresh thin horizontally bedded gray mudstone with 2 mm to 3 mm horizontal laminae from the quarry (B485), gray green thin bedded metasiltstone with layers of rusted opaques (B788), and thicker bedded weathered brown blocky siltstone (B490). An examination of a thin section of sample B788 showed angular to rounded quartz with severely embayed edges in a matrix of microcrystalline quartz and sericite.

Tillery Formation

The Phyllite unit (Cp) (Goldsmith and others, 1978) was previously assigned to the Tillery Formation by Conley and Bain (1965, p. 126) and was believed to be the metamorphosed equivalent of the argillite unit of the Tillery Formation along the border of the Slate belt. Conley and Bain also stated that in the Virgilina synclinorium the Tillery grades upward into greenstone flows. In a revised stratigraphy of the Tillery Formation, Seiders (1978, fig. 3) reports that, in the Ashboro quadrangle, it consists of mudstones, felsic volcanics, and mafic volcanics in ascending order.

The phyllite unit of Goldsmith and others (1978) is distributed in a wide band from northeastern Midland quadrangle southwest through the northeast corner of Bakers and eastern Matthews quadrangles. The phyllite is a blue gray aphanitic massive rock when fresh but weathers to brown to light brown masses of thin folia. Two thin sections of the phyllite (M912, M912B) reveal angular and euhedral quartz and feldspar in a cryptocrystalline and sericite groundmass.

Slightly east of the center of the phyllite belt, intermediate volcanics and mafic intrusives crop out along a line of topographic highs. The mafic rocks commonly are associated with large milky quartz veins more than 2 m thick, and concentrations of angular cobbles of milky quartz frequently occur in residual soils near the contact of mafic rocks and phyllite. The mafic rocks correlate well with Iredell loam mapped by Derrick and Perkins (1916).

A small area of felsic volcanic flows and tuffs containing carbonate crops out in northwestern Bakers and southwestern Midland quadrangles west of the Silver Hill fault. Stratigraphic relationships between the phyllite and the volcanic rocks were not conclusively determined by this study, but intermediate metavolcanic rock appeared to overlie or be interbedded with the phyllite. The apparent relationship between the phyllite and the underlying metavolcanic rocks seems to support conclusions of Conley and Bain (1965) that the phyllite is metamorphosed Tillery Formation. Coalified algae near the base of the Tillery Formation in Albemarle quadrangle, N.C., suggest an early Paleozoic age for the formation (Sieders and Wright, 1977, p. 9).

Conley and Bain (1965) assigned the lower part of the phyllite unit to the Uwharrie Formation. These rocks have been mapped here as part of the same volcanic unit that extends well into the Charlotte belt (Plate 1), where they appear to be in contact with rocks of quartz diorite, tonalite and granodiorite composition. U-Pb dates from near the top of the Uwharrie Formation in Ashboro and Albemarle quadrangles, North Carolina, suggest a date of 580 m.y. for this formation (Sieders and Wright, 1977, p. 9).

Charlotte belt

Rocks of the Charlotte belt in this area were described by LeGrand and Mundorff (1952, p. 5) as an injection of granite into "diorite." The relationship between the two rock types was thought to be so intricate that map units were based upon the predominance of gabbro, diorite, or granite. Butler (1966) mapped schist, diorite-tonalite, and gabbro units in York County, South Carolina. Goldsmith, Milton, and Wilson (1978) with the aid of geophysical data have further refined the geologic map of the area. Because of insufficient outcrops, the relationship between igneous and metamorphic rocks in this area has still not been well defined by reconnaissance mapping. However, the area has been intruded by three major pulses of magma resulting in 3 groups of plutonic units. The major emphasis in this paper is on the plutons of the Concord-Sálisbury supergroup.

1. Old Plutonic supergroup, plutons 545-495 m.y. that are quartz diorite to granodiorite in composition. They also are believed to underlie the Carolina slate belt and possibly the Kings

Mountain belt. These rocks are all premetamorphic.

2. Concord - Salisbury supergroup, plutons 425-350 m.y. which form sheet-like intrusions of gabbro with related diorite, monzonite and syenite; and smaller medium-grained Salisbury type granodiorite plutons. The gabbros formed high level magma chambers, 0 - 8 km deep, and produced volcanic complexes. These rocks are pre- syn- and post-metamorphic.

3. Landis supergroup, plutons 350-280 m.y. which usually form coarse-grained, K-feldspar-rich granitoids (Speers and others, 1979) that were emplaced below the gabbros. These rocks are all post-metamorphic.

Old Plutonic Complex

Butler (1966, p. 8) reported that metagranitic rocks underlie most of the Charlotte belt. The plutonic complex which underlies the study area is composed largely of rocks of quartz diorite, tonalite, and granodiorite of Old Plutonic suprgroup.

Old Plutonic supergroup rocks are usually massive, medium to coarse-grained, gray to brown in color, and have aggregates of biotite and commonly hornblende. The major minerals are plagioclase, quartz, and biotite. Minor minerals are microcline and hornblende with accessory epidote, opaques, apatite, zircon, and rarely sphene. Hand specimens do not often exhibit indications of metamorphism such as foliation, epidotisation, and shearing, but microscopic examination usually reveals quartz and feldspar with deeply embayed edges indicating recrystallization. Plagioclase is often altered to a mass of saussurite and epidote. If microcline is not a major constituent, it is usually found in the groundmass and rimming plagioclase rather than as large discrete crystals. Quartz diorite and tonalite are generally found west of the Catawaba River; tonalite and granodiorite east of it. Granodiorite predominates in the eastern part of the Charlotte belt.

The plutonic complex has been intruded by many small mafic bodies and dikes which commonly are metamorphosed to amphibolite. This is considered an indication that the mafic rock was emplaced prior to regional metamorphism; but some coarse-grained amphibolites are found near the edge of non-metamorphosed gabbro bodies. One very coarsely poikilitic sample (W206) was found near the edge of the Mecklenburg gabbro.

Quartz diorite, etc. is a unit that contains quartz diorite, biotite gneiss and garnetiferous muscovite biotite gneiss. The largest continuous area of biotite gneiss and schist occurs south of the Mecklenburg gabbro complex and has been incorporated into a map unit of "quartz diorite, etc." by Milton (oral communication). The unit forms a band 1.5 to 1 km (0.9 to 0.6 miles) wide which extends from southern Fort Mill quadrangle into northeast Weddington quadrangle, where it joins a band of intermediate volcanics trending in the same northeasterly direction.

Samples collected from the quartz diorite, etc., unit are quartz diorite, biotite gneiss, and garnetiferous quartz schist. The quartz diorite samples (FM205, FM1046) are medium-grained white rocks with black flecks of hornblende somewhat weathered. They contain zoned plagioclase with no alteration, green and brown hornblende, brown biotite, pyroxene, epidote, apatite, and sphene. This is the same composition as banded gneiss (W995) which crops out within the Mecklenburg complex and may be a border facies of the intrusion mentioned by Hermes (1966, p. 9). Outcrops of this unit and a lack of geophysical evidence of gabbro at depth may indicate that the overlying gabbro has been eroded away.

The biotite gneiss is a fine-grained well foliated rock with augen of recrystallized quartz and folia of biotite and muscovite. The garnetiferous quartz schist is fine-grained, has microgneissic structure, and contains small anhedral garnets.

Metavolcanic rocks cover a large part of the eastern Charlotte belt along its border with the Slate belt (LeGrande and Mundorff, 1952; Stuckey and Conrad, 1958; Butler, 1978; and Goldsmith and others, 1978). Milton (Goldsmith and others 1978) has interpreted the Charlotte belt-slate belt boundary in this area to be a sharp metamorphic boundary rather than a stratigraphic one. This implies that Uwharrie metavolcanics and Tillery phyllite units continue into the Charlotte belt at a higher metamorphic grade and may be equivalent to some of the rocks mapped as felsic metavolcanics (mvf, mvm) and gneiss.

Metavolcanic flows and tuffs of felsic (mvf) and mafic compositions (mvm) occur close to the border with the Slate belt. Metavolcanic rocks of intermediate compositon (mvi) occur further west in the Weddington quadrangle. There are isolated occurrences of felsic metavolcanics in the Charlotte West quadrangle, and a belt of intermediate and felsic metavolcanic rocks (mv) occurs (mvf) in the Belmont quadrangle.

Vertical beds of greenstone that strike W60E, 90 outcrop in a stream bed 1.1 km (0.7 miles) southeast of Matthews and northeast of Road 1009. About 15 m (59 feet) southeast of the stream and higher in the valley, there are boulders of light gray metamorphosed felsic porphyry. Two samples from two beds of the greenish gray rocks were taken. One sample contains thin layers of amphibole quartz and quartz-epidote with secondary carbonate; and the other sample is amphibolite schist.

The metavolcanic rocks of intermediate composition that crop out in the Charlotte East quadrangle are near exposures of medium-grained granite, granodiorite and tonalite. Samples of these rocks come from massive exposures in a stream channel at CE982. The rocks contain irregularly shaped blocks that vary in grain size and color. Some rock is dark gray and aphanitic with light tabular phenocrysts of plagioclase (3.5 mm) and occasional pyrite. This rock breaks with a conchoidal fracture. The aphanitic groundmass has a metamorphosed hyalopilitic texture made up of tabular feldspar laths in recrystallized interstitial material.

Quartz schist of Nanny Mountain is located in western Lake Wylie quadrangle. It is the best known exposure of quartz schist in the study area. According to Bulter (1966 and 1971), the outcrop pattern of quartzites suggests a fold with a north-plunging axis. These rocks are up to 9 m (30 feet) thick, cap ridges, and grade into underlying mica schists. The quartzite is light gray, commonly stained yellow or red by weathered pyrite, and contains limonite pseudomorphs of pyrite and iron oxide coated vugs. Where sericite is abundant, the quartzite has a distinct cleavage.

Other quartzites and quartz schists occur in the vicinity. Belts of kyanite- and sillimanite-bearing quartzites occur with schist, gneiss, and amphibolite in the Kings Mountain belt (Horton and Butler, 1977, p. 89) (fig. 1). Discontinuous bodies of quartz schists have been mapped along the western edge and within the Charlotte belt by Butler (1966) and Milton (Goldsmith and others, 1978). These quartzites and mica schists represent metamorphosed sandstones and shales (Butler, 1966, p. 7).

Concord-Salisbury supergroup

Gabbro plutons occur in an arcuate zone which extends 720 km (447 miles) from Farmington, North Carolina to Monticello, Georgia, and which contains about 30 separate gabbro-diorite plutons (Butler and Ragland, 1969, p. 176). Almost all of these occur in the Charlotte belt. The study area contains the large Mecklenburg gabbro complex and another large gabbro pluton west of Weddington, North Carolina, which is called the "Weddington gabbro" in this report. Two smaller gabbro bodies have been mapped in the area by Butler (1966) and Milton (Goldsmith and others, 1978). The Mill Creek gabbro unit is located at the west end of the area in metavolcanic rocks and the other metagabbro is in northern Charlotte West quadrangle in felsic metavolcanic rocks (Plate 1). All these gabbros are included in the Concord-Salisbury supergroup.

The Mecklenburg gabbro complex is the largest of the gabbro bodies and extends from eastern Belmont and Lake Wylie quadrangles to northeastern Weddington quadrangle. The area of outcrop is approximately 95 square km (43 sq. miles) (Hermes, 1966, p. 7). The complex contains cupolas of olivine gabbronorite (Pzgbm) in a larger hornblende gabbro (Pzmgb) (called metagabbro by Hermes, 1966). It also includes the Pineville olivine gabbronorite (Butler and Ragland, 1969, p. 168), and associated mafic metavolcanics (Goldsmith and others, 1980).

Gabbroic rocks of the complex generally weather to dark brown Mecklenburg and Iredell Series soils on which groups of large gray to black, rounded, massive, residual boulders occur. This relationship of mafic rock to soil type is so consistent that it was used by Hermes to map contacts of the gabbro. These soils types cover almost the same area as the Mecklenburg gravity anomaly, and may be as reliable an indication of gabbro contacts as geologic mapping.

Hermes (1968) made a very thorough petrographic and chemical study of the gabbro rocks. He describes the hornblende gabbro as a dark gray to gray-green, fine to medium-grained rock with granoblastic, porphyritic, and poikilitic textures. Major minerals are plagioclase, green to brown hornblende, biotite, clinopyroxene, minor orthopyroxenes, epidote and abundant opaques and apatite accessory minerals. A large exposure of the hornblende gabbro at the Arrowood quarry is cut by a vertical fine-grained metamorphosed mafic dike, and a vertical quartz vein, rich in sulfides, both of which strike in an east-west direction. Reddish gray medium-grained felsic dikes up to 1 m (3 ft.) thick and a similarly oriented shear zone also cut the hornblende gabbro in a north-south direction and dip approximately 50 degrees east.

The intruding olivine gabbronorite is difficult to distinguish from the hornblende gabbro in hand specimens. The olivine gabbronorite has hypidiomorphic-granular subophitic, and poikilitic textures; and contains plagioclase, olivine, hypersthene, augite, minor hornblende and biotite which usually form reaction rims on pyroxene and opaques. The primary difference between the two rocks is that the olivine gabbronorite always contains olivine and the hornblende gabbro contains more hydrous minerals, hornblende and biotite and no olivine (Hermes, 1966, p. 3).

The mafic metavolcanic unit (mvmc) of the Mecklenburg complex (Goldsmith and others, 1978) consists of fine to medium-grained green mafic rocks, metapegmatites, and dark saprolite that are cut by many aplite and mafic dikes.

Weddington gabbro (Pzgbw) is located in southeastern Weddington quadrangle. Large boulders of light to dark gray medium-grained leucogabbro crop out from beneath Iredell soils along the road 3.7 km

(2.3 miles) west southwest of Weddington, between McBride Branch and Marvin Branch of Six Mile Creek. On the property of Kerr Farms (fig. 2), troctolite and olivine gabbronorite crop out along with exposures of black aphanitic sillimanite bearing hornfels. The rock types also include pyroxene-hornblende gabbronorite. The textures in the gabbroic rocks are hypidiomorphic-granular, subophitic and poikilitic with crystals of pyroxene up to 5 cm long enclosing plagioclase, olivine and opaques. The major minerals are plagioclase, olivine, orthopyroxene, clinopyroxene, minor opaques, hornblende, biotite, and a rare grain of green spinel in opaques. Olivine commonly contains rims of orthopyroxene, clinopyroxene and hornblende; and magnetite is commonly rimmed with hornblende and biotite.

Sparse sampling indicates that the gabbro has a contact metamorphic hornfels of dark blue to black aphanitic rock composed of fine-grained granoblastic quartz, feldspar, and radiating groups of sillimanite. The pluton also has a border facies or upper level of poikilitic hornblende-pyroxene gabbronorite and olivine gabbronorite; troctolite may occur as a core, lower unit, or as layers in olivine gabbronorite.

Small granitoid intrusions, usually associated with radioactivity anomalies caused by K^{40} (U.S. Department of Energy, 1979), occur as small pods of potassim-rich granitic rocks around the periphery of the major gabbroic intrusions. Eagle Lake granodiorite, has been identified by a radioactivity anomaly north of the Mecklenburg complex, and Providence Church monzonite-syenite is associated with an anomaly around the northeast rim of the Weddington gabbro.

Providence Church monzonite-syenite are medium-grained hornblende-bearing rocks exposed near Providence Church in Weddington quadrangle. West of the Providence Church buildings (W466C), a large area of medium-grained brown monzonite with 2 mm to 10 mm black flecks of hornblende crops outs as large boulders and as a massive rock ledge. The monzonite is composed of xenomorphic phenocrysts of microcline in a groundmass of anhedral microcline, plagioclase, minor quartz, hornblende, biotite, opaques, and accessory apatite and sphene. One kilometer north, hornblende syenite (W466A) and quartz syenite (W466E) outcrop along with a monzonite porphyry (W466A) containing relic pyroxene. Another monzonite body is located in southern Charlotte East quadrangle on the northern border of the hornblende gabbro body north of Providence Church (Milton, oral communication). No samples were obtained. These rocks are thought to be gabbro differentiates and part of the Concord-Salisbury supergroup.

Eagle Lake granodiorite (Pzgdie) is the only known young granitic pluton associated with the Mecklenburg gabbro. It is a fine- to medium-grained granodiorite located in central Charlotte West quadrangle. The granodiorite is gray with black flecks of biotite and weathers light tan. A fine-grained foliated sample has allotrimorphic-granular texture with microphenocrysts of saussurtized plagioclase in layers of anhedral plagioclase, quartz, untwinned feldspar, microcline, and biotite. Because the composition of the pluton is granodiorite and it is associated with a large gabbro body it is considered part of the Concord-Salisbury supergroup.

Stallings granodiorite (Pzgdis) is a light brown medium-grained rock (MA855) which crops out near Stallings just east of the Mecklenburg County line. At Eastwood Forest Church rounded boulders of the granodiorite occur on light colored Durham series soils rich in quartz grains. The rock is composed of quartz, cream-colored plagioclase, and minor biotite in a pinkish groundmass. Microscopic examination reveals hypidiomorphic-granular microporphyritic texture with phenocrysts of quartz, highly altered plagioclase and microcline. Plagioclase is often reduced to masses of sericite and epidote. Potassium feldspar usually occurs as small commonly euhedral crystals of microcline in the groundmass or interfingers with relic plagioclase in phenocrysts of altered perthite.

An outcrop of metavolcanic rock of dacite composition with prominent flow foliation, in a stream bed 1.4 km (0.9 miles) northwest of Eastwood Forest Church on the southwest side of Road 1009, may have been a lava associated with this granodiorite. The granodiorite composition and the association with volcanic rock suggest that the Stallings granodiorite may have been part of a high level magma chamber and part of the Concord Salisbury supergroup.

Landis supergroup

Weddington granite (Pzgrw) is located in southwest Matthews quadrangle. At Muddys Run and Highway 84 (MA 868) there is an exposure of brown coarse-grained granite with prominent pink microcline. This granite has an allotrimorphic-granular texture: Major minerals are microcline, plagioclase with minor sericite alteration, quartz, minor amounts of biotite and opaques, and accessory apatite and euhedral sphene. At sample location MA865, 4.5 km (2.8 miles) north of MA868 on the south side of Road 3445 Mecklenburg County, 0.9 km west of the Union County line, there is an exposure of brown porphyritic granite with pinkish 2 cm phenocrysts of microcline in a quartz, plagioclase, and biotite groundmass with accessory apatite and sphene. These two samples, MA865 and MA868, are part of a typical post-metamorphic Landis supergroup granite pluton.

Modal analysis of some Concord-Salisbury and Old Plutonic supergroup rocks

Modal analyses were made to determine the mineral compositon of 19 samples of plutonic rock (Table 1); 12 samples of Weddington gabbro, 1 sample of Pineville gabbro, and 6 samples of plutonic complex granitic rocks. Counts of 1100 to 1300 per analysis were made giving an accuracy of ± 2% according to Kalsbeek (1969). Plagioclase anorthite content was determined by albite twin extinction angles according to the Michel-Levy's method (Kerr, 1959, p. 258). Anorthite content of grabbros is generally low because most measurements were from small grains; large plagioclase grains were usually not suitably orientated for measuring. Modal analysis data were also used to classify the samples (figs. 6, 7) according to the nomenclature recommended by the IUGS Subcommission on the Systematics of Igneous Rocks (Geotimes, 1973).

Petrology and petrography of some gabbro rocks

The gabbros include troctolite, olivine gabbronorite and pyroxene-hornblende gabbronorite. The two samples of troctolite (WKF4A, WKF5, Table 1) are from Kerr Farms towards the center of the Weddington gabbro. The hand samples are dark gray, medium-grained and equigranular.

Troctolite has major minerals of plagioclase (61% to 63%) and olivine (32% to 35%). Opaques (1% to 2%) and biotite (0% to 0.5%) are minor phases which typically form reaction rims on the major minerals. Plagioclase, has an average An content of 51%, is typically euhedral, and up to 1.8 mm in length. It is the cumulus crystal and olivine is the interstitial mineral. Other mafic minerals occur as clots adjacent to large subhedral to anhedral crystals of olivine up to 3 mm in length. Sample WKF4 contains areas of green altered olivine which must be of secondary origin. Opaques, probably magnetite, occur as small cubic, triangular, and octahedral grains up to 0.8 mm in diameter in both plagioclase and olivine; but masses of small grains are found in the cracks of olivine, and, therefore, must be a late stage magmatic occurrence. A few anhedral segregations of opaques up to 0.5 mm, usually rimmed by hornblende, occur within and adjacent to olivine in the mafic clots. Brown hornblende usually forms 0.3 mm rims on olivine and opaques. Pyroxene almost always is found as 0.2 to 0.8 mm rims on olivine and some, in turn, are rimmed by hornblende. Some biotite forms isolated crystals up to 1 mm, but most biotite is associated with hornblende and opaques.

The order of crystallization is: small euhedral opaques - plagioclase - plagioclase and olivine - olivine and opaques - finally, reaction with residual or other liquids to form pyroxene, hornblende, opaques biotite.

Olivine gabbronorite made up the bulk of the gabbro sampled. One sample of Pineville gabbronorite (FM201) is light gray and has incipient foliation. The main constituents of the rock are plagioclase 70%, olivine 12%, and clinopyroxene 9%. Minor amounts of hornblende (4.1%), orthopyroxene (2%), and opaques (1%) are typically associated with the main mafic phases.

Plagioclase has an An content of 50%, occurs as euhedral grains up to 7 mm in length, and large crystals are commonly bent. Olivine usually forms subhedral to anhedral grains 3 mm to 4 mm, and is commonly rimmed by orthopyroxene or hornblende and frequently both minerals. Clinopyroxene forms large poikilitic plates which contain exsolved opaques along cleavage planes. The large poikilitic crystals often

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Table 1. Modal data (volume %) of rocks from southern Mecklenburg County and vicinity ( ) = number of determinations; Tr=trace=<0.2%; other = usually brown amorphous secondary alteration of mafic minerals.

Table 1. Modal data (volume %) of Southern Mecklenburg Co. and vicinity rocks
( ) = number of determinations; Tr=trace=<0.2%; other = usually brown amorphous secondary alteration of mafic minerals

Sample	Plag.	Oliv.	Opx.	Cpx.	hbl.	bio	opaq.	apat.	epid.	qtz	k-spar.	musc.	spinel	other	An-Plag.
troctolite															
WKF 4A	60.8	35.1	0.5	0.0	0.6	0.0	2.3							0.7	48 (10)
WKF 5	62.7	32.3	0.5	0.2	1.0	0.5	0.7							1.9	55 (10)
Olivine Gabbronorite															
WKF 2	67.3	10.7	6.9	5.3	2.6	1.1	3.3						Tr	2.8	45 (9)
WKF 3	64.7	16.3	1.2	10.8	3.2	0.0	3.2						Tr	0.7	43 (10)
WKF 3B	63.5	16.7	2.1	11.0	3.7	0.0	2.6						Tr	0.2	37 (12)
WKF 5A	65.4	12.8	3.1	9.9	1.5	0.1	6.1						Tr	1.1	46 (10)
W1003B1	63.0	19.1	1.3	10.4	2.6	0.1	2.9						Tr	0.5	44 (10)
W1003	60.6	11.5	9.5	11.0	4.0	0.5	1.3						Tr	1.5	43 (7)
W1003X1	59.1	6.0	7.3	11.4	2.8	1.5	5.5						Tr	6.4	41 (9)
W1003X2	66.0	15.5	0.8	11.0	0.6	0.1	4.9							0.1	41 (10)
W1003X3	62.6	13.5	1.1	15.7	2.7	0.1	3.7						Tr	0.5	43 (10)
W1003X4	62.6	13.8	0.9	16.5	1.8	0.3	3.6						Tr	0.5	47 (10)
FM201	70.4	11.9	2.4	8.6	4.4	0.2	1.5						Tr	0.5	50 (9)
Pyroxene-hornblende gabbronorite															
WKF 2A	63.8	11.4	5.2	5.0	7.4	0.2	4.2						Tr	2.8	44 (10)
Quartz monzodiorite															
LW1145	61.0					18.0	1.0	Tr	5.0	14.0	1.0				
Tonalite															
CW1111	54.0					9.0	<1	Tr	<1	35	1.0	<1			30
W209	51.0					11.0	<1		20	33.0	3.0	Tr			
Granodiorite															
MAE55	40.0					1.0	1.0		1.0	38.0	18.0	Tr			
CE932	47.0					7.0	<1		2.0	25.0	19.0	<1			
Monzonite															
W466C	44.0				4.0	1.0	1.0	Tr	Tr	4.0	44.0				
Weddington															
Av olivine gabbronorite	63.5	13.6	3.4	11.3	2.6	0.4	3.7						Tr	0.9	43
Range	59.-67	6.-19.	0.8-9.	5.-16.	0.6-4.	0.-1.5	2.-6.							0.5-6.	37-47
Av. troctolite	61.8	33.7	0.5	0.1	0.8	0.3	1.5							1.3	51

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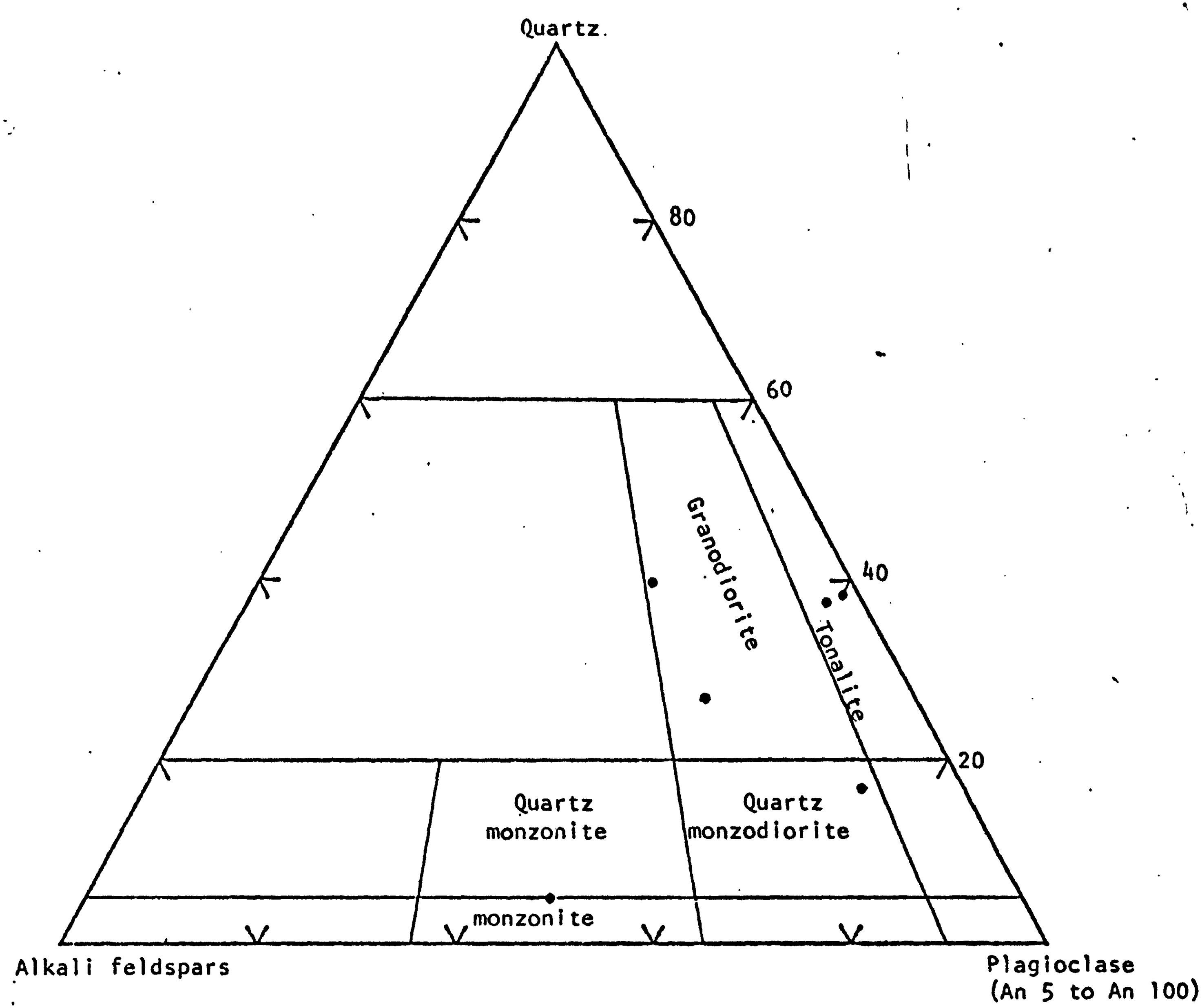
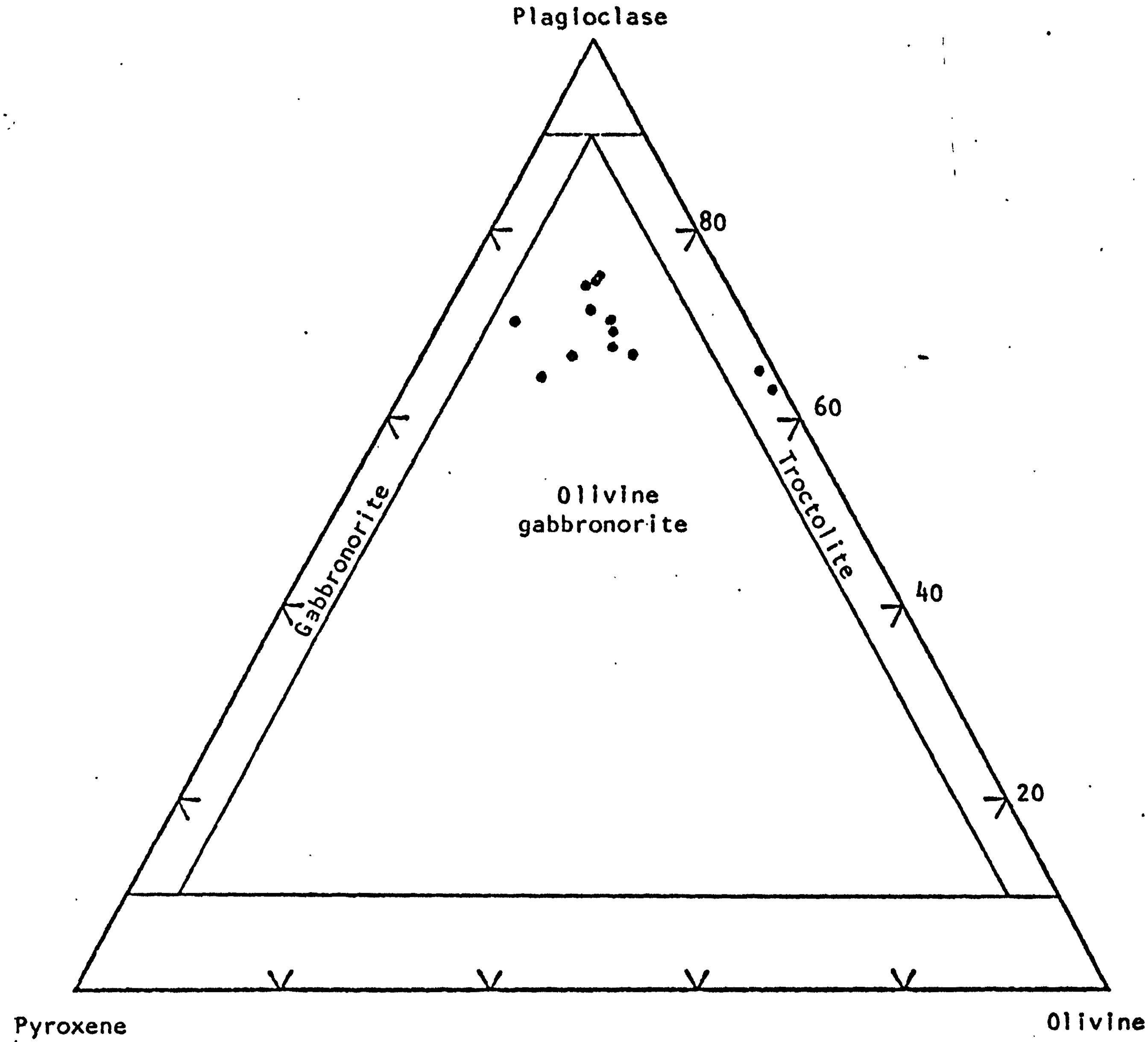
Figure 6. Modal diagram and classification of granitoid rocks of southern Mecklenburg County and vicinity (after IUGS, 1973.


Quartz.
80
60
40
20
Granodiorite
Tonalite
Quartz
monzonite
Quartz
monzodiorite
monzonite
Alkali feldspars
Plagioclase
(An 5 to An 100)

32

Figure 7. Modal diagram and classification of gabbroic rocks of southern Mecklenburg County and vicinity (after IUGS, 1973.


Plagioclase
80
60
40
20
Troctolite
Olivine
gabbronorite
Gabbronorite
Pyroxene
Olivine

contain orthopyroxene up to 9 mm, and are usually rimmed by hornblende. Orthopyroxene occurs as discrete grains as well as in association with olivine and is pleochroic from pink to pale green. Anhedral opaques, usually rimmed by hornblende, often contain green spinel and myrmikitic intergrowths of orthopyroxene.

The Weddington olivine gabbronorite is similar to the Pineville, but contains less plagioclase and more opaques. The modes of 11 samples average 63% plagioclase, 14% olivine, 11% clinopyroxene, 4% opaques, 3% hornblende and orthopyroxene, and 0.4% biotite. Plagioclase has an average An content of 43% and reaches lengths of 10 mm. The An content of plagioclase is low because large grains, which have higher An content, were not suitably oriented for measuring. Olivine is commonly rounded, 0.9 to 1.5 mm, and occurs in an equilibrium assemblage with plagioclase and opaques; it occurs in disequilibrium assemblage, altering to orthopyroxene, with clinopyroxene, hornblende and opaques rimmed by biotite and hornblende; and it is also preserved in hornblende and clinopyroxene crystals showing no alteration rims. Clinopyroxene usually occurs as poikilitic plates enclosing rounded olivine or orthopyroxene and small plagioclase. It also has distinct cleavage planes containing exsolved opaques. Hornblende generally occurs as rims on other mafic minerals, as discrete grain in clots of mafic minerals, and commonly as poikilitic crystals after pyroxenes. Orthopyroxene also forms poikilitic crystals and is pleochroic from pink to pale green. Biotite is typically associated with opaques, but in areas where hornblende is abundant it forms isolated grains. Opaques are commonly rimmed by hornblende or biotite and contain green spinel. But opaques also occur in equilibrium with olivine and plagioclase.

The one sample of pyroxene-hornblende gabbronorite (WKF2A), from

Kerr Farms, contains 64% plagioclase, 11% olivine, 7% hornblende, and 0.2% biotite. This sample has some poikilitic crystals almost completely composed of hornblende and contains lithic fragments of xenomorphic hornblende and plagioclase. This sample location is 200 m north of a fine-grained sillimanite-bearing hornfels or xenolith, and may represent a contact facies of the pluton.

Gabbronorite is characterized by poikilitic pyroxenes, anhedral segregations of opaques rimmed by hornblende and biotite. Equilibrium assemblages of opaques, olivine, and plagioclase exist in close proximity to disequilibrium assemblages of olivine, pyroxene, and hydrous mafic minerals. The two normally incompatible mineral assemblages indicate that the rock was not completely consolidated when the hydrous liquids began altering the mineralogy. Medlin (1968, p. 77) describes similar reactions in the Buffalo gabbro pluton at the edge of the Kings Mountain belt in South Carolina. The mineral assemblage he describes contains green fibrous amphibole instead of the brown biotite of the Mecklenburg or Weddington gabbros; but, he describes brown amphibole intergrown with green amphibole and both having identical orientation and optical properties.

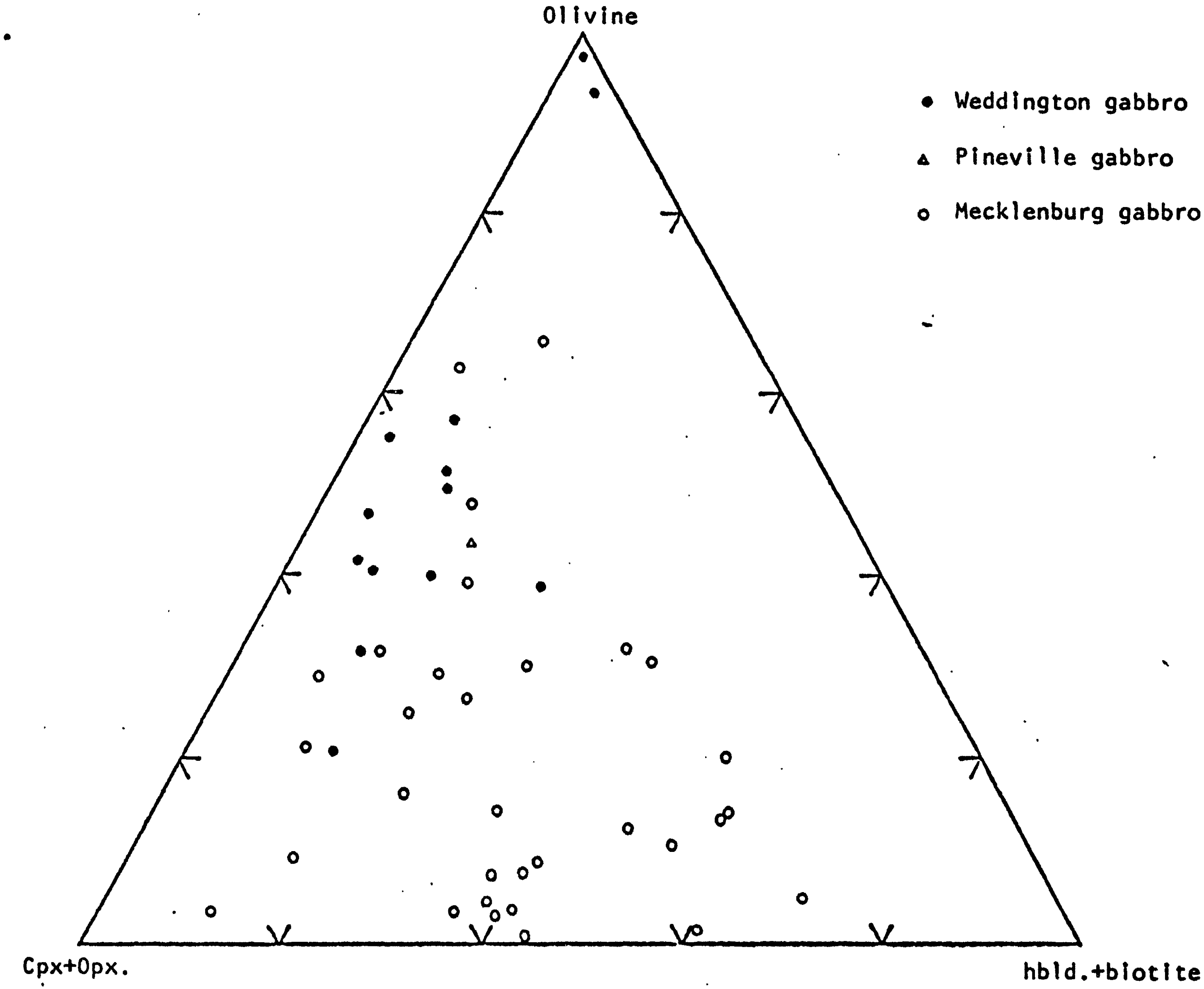
> "Corona development in the Buffalo Complex ranges from fresh olivine grains without rims to ones in which the olivine is completely replaced by orthopyroxene or fibrous green amphibole. This development seems to occur in the following manner. First, the olivine is rimmed by orthopyroxene which may or may not consume the olivine grain. Concurrent or subsequent to this, reaction at the orthopyroxene-plagioclase interface forms fibrous green amphibole accompanied by opaque grains

and green spinel" (p. 77).

All of these reactions involve olivine and Medlin discusses three explanations for them: (1) late magmatic crystal-magma reactions (2) post magmatic-deuteric or mineral-magmatic fluid reactions, (3) metamorphic solid-solid reactions due to regional or thermal metamorphism. Regional metamorphism is eliminated because of the lack of deformation of the pluton, and Medlin concluded that the remaining processes occurred during slow cooling of the pluton. The symplectic textures in the Buffalo Complex were produced by autometamorphism (Medlin, 1968, p. 83). Hermes (1968, p. 282) concluded that the crystal-liquid reactions occurred during the "waning magmatic stages." The serpentinized part of WKF4 indicates that post consolidation deuteric solutions may have been active in the final phases of consolidation; and the pelitic xenolith WKF1 suggests that all of the late stage volatiles may not have been residual, but could have been supplied in part by xenoliths. The prominent opaques probably have a large magnetite content which may explain the high NRM of these rocks.

A plot of the Weddington samples on Hermes' (1968) triangular plot of mafic silicates of the Mecklenburg gabbro (fig. 8), shows most of the Weddington samples grouped about 50% olivine, 50% pyroxene, and less than 15% hydrous mafic minerals (hornblende and biotite). The one sample of the Pineville gabbro (FM 201) plots with the Weddington olivine gabbronorites. Most of Hermes' samples vary widely in composition indicating the complex structure of the Mecklenburg gabbro stock and may also reflect the influence of volatiles introduced by xenoliths and roof pendants. The Weddington gabbro has a more mafic composition than the Mecklenburg, and both groups of samples show a

Figure 8. Variation of modal proportions of mafic minerals in Weddington, Pineville, and Mecklenburg gabbro rocks samples. Mecklenburg data (open circles) from Hermes (1968, p. 278, fig. 5).


Olivine
Weddington gabbro
Pineville gabbro
Mecklenburg gabbro
Cpx+Opx.
hbld.+biotite

trend from a Weddington olivine gabbronorite toward a more differentiated and hydrated pyroxene-hornblende gabbronorite.

Structures

Three major faults have been mapped previously in the study area and all of them are located along the Charlotte belt-Slate belt boundary. They are the Gold Hill, the Silver Hill and a fault west of these (Butler, 1978; Hatcher and Butler, 1979) in the Charlotte belt. Two new faults are suggested by this study--a minor splay of the Silver Hill fault and the South Mecklenburg fault zone.

Gold Hill fault

The Gold Hill-Silver Hill fault system has been used to explain the sharp and distinct boundary between the Charlotte Belt amphibolite facies and the Slate belt greenschist facies terranes (Laney, 1910; Pogue, 1910; Butler, 1977, p. 125; Butler 1978; Butler and Fullagar, 1978; Hatcher and Butler, 1979). The Gold Hill fault was originally described by Laney (1910, p. 68-71) in the Gold Hill mining district, Rowan County as "a great fault of undetermined throw" that separated the plutonic rocks of the Charlotte belt from the slates of the Slate belt. The existence of this fault, like most faults in the Piedmont, is based upon secondary evidence. The following is Laney's evidence for the fault:

"(1) Granite-slate contact is not metamorphosed.

(2) Granite dikes do not intrude slates at granite-slate contacts as they do at diorite-granite contacts.

(3) Minor faults parallel the contact of the belts.

(4) Joint planes with slickensides parallel the contact of the belts.

(5) Streams follow the belt contact rather than the schistosity.

(6) The belt contact is marked by a line of mineral springs.

(7) There is mineralization along a zone of fissures parallel to the belt contact."

Butler (1977, p. 125) describes the fault as a "ductile" fault that truncates a granite pluton, cuts across a fold system near Gold Hill, North Carolina, and probably extends across southwestern Lancaster County and southeastern York County, South Carolina where it is marked by strongly deformed felsic volcanic rocks as at the type locality.

Tobisch and Glover (1969) showed that the Carolina slate belt-Charlotte belt boundary coincided with the transition to amphibolite facies in the area of the Virginia-North Carolina state line. Milton (Goldsmith and others, 1978) also interpreted the fault as a metamorphic boundary at the west edge of the phyllite unit. In Plate 1, the trace of the Gold Hill fault is shown as the metamorphic boundary between phyllite and metavolcanic rocks. Part of the Gold Hill fault may pass between the Weddington Gabbro and Weddington granite.

<u>Silver Hill fault</u>

The Silver Hill fault was described by Laney (1910, p. 71) and Pougue (1910, p. 88) as a west dipping thrust fault that is also defined by secondary features such as an escarpment along the east side of Flat Swamp Ridge, the abrupt ending of stratigraphic units at the ridge, and parallelism of the fault to all of the features defining the Gold Hill fault. Hatcher and Butler (1979, p. 106) continued the fault into South Carolina; and on the basis of radiometric dates of a sheared granitic pluton, Butler and Fullagar (1978, p. 465) concluded that ductile deformation in the Gold Hill-Silver Hill shear zone occurred between 400 and 368 m.y. Milton (Goldsmith and others, 1978) ended the Silver Hill fault in the northern part of Bakers quadrangle but continued a metamorphic boundary between phyllite and mudstone to the edge of the Charlotte 2^{o} sheet through a synform outcrop pattern of mafic intrusive rock.

In this study the fault mapped by Milton (Goldsmith and others, 1978) is extended to the south edge of the map and a southwest splay of the fault in southern Midland and northern Bakers quadrangles is added. Evidence for these faults is based upon aeroradioactivity and gravity data, and the offset of mapped mafic intrusive units.

The South Mecklenburg fault zone

Like all other faults in the Piedmont, the south Mecklenburg fault zone (Plate 2) is manifested by geophysical anomalies and secondary geologic evidence rather than by primary fault surfaces and direct evidence of displacement. The structure is best expressed by geology and gravity, and is poorly defined by aeroradioactivity and aeromagnetics.

The geologic expression of the fault zone is the northern edge of quartz schist (qs), intermediate metavolcanics (mvi), Providence Church monzonite (Pzmz), and the contact between granodiorite (mqdi) of the old plutonic complex and the metavolcanics (mvf) west of the Stallings granodiorite. Along the zone units of different stratigraphic and structural levels and ages are juxtaposed. The plane of the fault may dip to the south because gravity anomalies (Plate 9, 10) indicate that the structure is deeper south of its surface expression. Displacement along the fault may be only a few hundred meters at most and may be the result of ductile strike-slip deformation rather than vertical movement.

Other faults

The geologic map of the Charlotte quadrangle by Butler (1978) shows a new major fault west of the Gold Hill-Silver Hill shear zone in the Charlotte belt (Plate 2). The fault begins in Cabarrus County passes through eastern Mint Hill quadrangle and dies out at the west side of the Stallings granodiorite. Butler shows this fault as the western contact of a felsic metavolcanic unit west of the Gold Hill fault.

REGIONAL GEOPHYSICAL STUDY

Introduction

Aeroradioactivity, aeromagnetic, and gravity surveys are rapid methods of gathering informtion about rocks and structures at different levels within the earth. These methods have been utilized widely in exploration geology to help locate and evalute economic mineral deposits.

Radioactivity methods provide information on gamma radiation from the surface to a depth of less than 0.3 meters (Pemberton, 1967, p. 424); and the magnetic method can detect magnetic rocks from the surface to the depth of the Curie temperature of magnetite. The effectiveness of both methods is limited by flight elevation and spacing between flight lines. Increasing flight elevation smooths out the anomaly causing a loss of small wavelength details, and features smaller than flight-line spacing may not be detected or adequately defined by contouring the results. Further details on aeroradioactivity and magnetic methods are found in Appendix A.

Gravity methods record lateral variations in mass within the earth, and provide information about rock densities from the surface to deep within the crust and mantle. The size of features, defined by this method, is also limited by the distance between gravity stations and by the inherent density contrast between buried structural elements.

Geophysical survey data of the study area, along with soil survey data were used to aid geologic mapping and interpretation. Aeroradioactivity, aeromagnetic and gravity transparencies at 1:62,500 scale were used to correlate the different data bases with geologic maps of similar scale; anomaly-causing lithologic units, their possible limits, and their structural trends were thus identified. The Talwani 2-dimensional computer program was used to model cross-sections which include major anomalies and associated geologic structures. The CPS Computer program by Unitech, Inc. (1976) at the U.S. Geological Survey, Reston, Va. was used to contour Bouguer gravity map and plot gravity stations (Plates 3 and 4).

RADIOACTIVITY

Regional setting

The regional aeroradioactivity in the area of the study (U.S. Geological Survey, in preparation) shows distinct bands of aeroradioactivity anomalies which coincide with the Piedmont lithotectonic belts. The Slate belt is an area of relatively high radioactivity; the Charlotte belt is generally low except for potassium-rich plutons; and the Kings Mountain belt has values that are transitional between the lows of the Charlotte belt and the very high values of the Inner Piedmont.

Aeroradioactivity map of the study area

Compilation

The aeroradioactivity map of the study area (plate 4,8) was assembled from parts of 3 U.S. Geological Survey Open-file maps (U.S. Geological Survey, 1976c, 1976d, 1978b). The data for these maps were from surveys flown with a total count gamma ray instrument, at a constant altitude of 152 m (500 feet) above the ground surface, and along east-west flight lines one mile apart. Radiation units of the three maps differed in value and were correlated by matching anomalies, rescaling, and assigning new values to one of the surveys. The map of the study area was compiled on transparent mylar at a scale of 1:62,500. It was overlain on a similar scale geologic map of the area, and anomalies and anomaly patterns were visually correlated with mapped lithologic units. The mylar was used in conjunction with other geophysical maps to aid geologic mapping and interpretation. Spectral radiation data (U.S. Department of Energy, 1979), was used to identify the relative proportions of the radioactive source isotopes, potassium 40, bismouth 214 (uranium) and thallium 208 (thorium) which contribute to the total count signal.

Description

The total count aeroradioactivity map of the study area (Plate 5, 6,) shows the distinct characteristics of each regional belt. The Slate belt, which includes eastern Midland and Matthews quadrangles and all of Bakers quadrangle, has levels generally greater than 250 counts per second (c/s). The Charlotte belt, which occupies the rest of the map, is dominated by small anomalies of less than 250 c/s, has prominent highs (>500 c/s), and four major low areas.

The Slate belt is occupied by a band of anomalies (200-300 c/s) with a northeast to southwest trend. The band extends from the northeastern corner of the map to southeastern Matthews quadrangle, over the phyllite unit. East of this band, are two distinct high areas containing anomalies greater than 500 c/s. One is in southeast Bakers quadrangle over the Cid Formation; the other is in east Midland and northeast Bakers quadrangles over the Millingsport Formation. Also on the east side of the band, 2 low anomalies of less than 250 c/s in western Midland quadrangles have straight edges where they encounter the trace of the Silver Hill fault.

The Charlotte belt-Carolina slate belt boundary is marked by a sharp change in anomaly direction from northeast-southwest in the Slate belt to north-south in the Charlotte belt. The low aeroradioactivity in the northeast Charlotte belt increases to the west in the Charlotte West quadrangle. One small high of 600 c/s, the Red Branch Church high, is north of Mint Hill, over a young granodiorite; but there are very low values of aeroradioactivity (less than 100 c/s) over the Stallings granodiorite and metavolcanic rocks.

West of Stallings, aeroradioactivity highs (Eagle Lake, Olde Providence, and Forest Lake) are concentrated around the periphery of 4 northwest trending lows in northern Weddington, southern Charlotte West, and Charlotte East quadrangles. The northwest trending lows are over rocks of the Mecklenburg gabbro complex.

The largest area of high aeroradioactivity on the map is in Fort Mill and Lake Wylie quadrangles, south of the Mecklenburg gabbro complex. The Forest Lake anomaly contains the highest intensity on the map, 1000 c/s, and is over Old Plutonic complex granodiorite and near quartz diorite and schist. West of the high, a series of north-south trending lows of less than 100 c/s are due to water shielding) follow the course of the Catawba River. These lows lie in an area of otherwise high aeroradioactivity. West of the river, the anomalies have a distinctive parallel north-south trend which may be due in part, to different contouring technique, but is still thought to reflect the linear trend of rock units in that area.

Radioactivity summary

These distinctive anomaly patterns and distributions of intensities are a result of the radioactive elements found in the residual soils and rock outcrops of the mapped area, the chemical contrast between adjacent units, the flight line spacing, and the interpretive contouring. The distribution of elements and soils are influenced by the variable composition of the igneous and metamorphosed rocks. In general:

(1) aeroradioactivity lows are associated with gabbroic and metavolcanic rocks.

(2) Highs are associated with mudstone in the Slate belt; and with gneisses, schists, and young granitoid plutons within the

Charlotte belt.

(3) The high radioactivity is indicative of a high potassium content of the rocks.

MAGNETICS

Introduction

The magnetic methods employed in this study include measurements of magnetic susceptibility and the natural remanent magnetism (NRM) of rocks. Total intensity aeromagnetic surveys measure variations in the earth's magnetic field. These variations appear as anomalous magnetic values on aeromagnetic maps, and when the effect of earth's magnetic field is removed, the resultant anomalies represent those caused mainly by the shallowest magnetic rocks of the upper crust. The magnetism of rocks is attributed largely to the occurrence of magnetite.

Regional setting

The aeromagnetic map of the Charlotte $1^{o}x2^{o}$ quadrangle (Daniels and Zietz,(1980) (fig. 9) shows distinct anomaly patterns that closely coincide with the major Piedmont lithotectonic belts. The Charlotte belt contains many high amplitude anomalies that range from circular to oval in shape, but the overall level of magnetic intensity in the belt is low. Several prominent magnetic highs are concentrated in the central and southeastern part of the Charlotte belt. Some of these highs are included in the study area.

Smaller magnetic anomalies are concentrated along the eastern edge of the Charlotte belt where the anomaly pattern changes abruptly from short wavelength anomalies to predominately long-wavelength anomalies. This sharp change in anomaly pattern helps define the Charlotte belt-Slate belt boundary. The Carolina slate belt, in this area, is dominated by one large magnetic high and its distal edges extend to the

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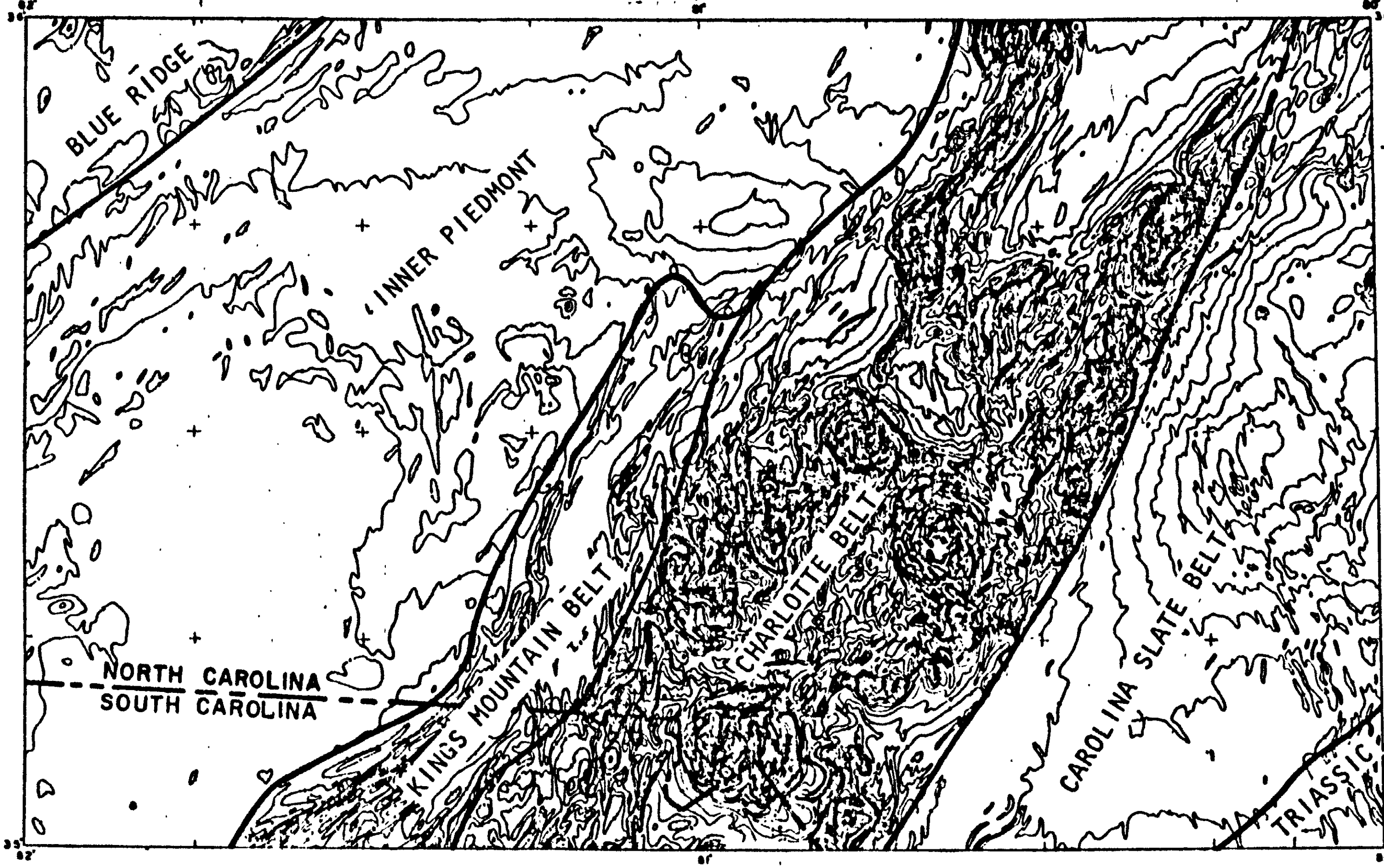
Figure 9. Map showing Piedmont belt boundaries and magnetic contours (Daniels and Zietz, 1980)


BLUE RIDGE
INNER PIEDMONT
NORTH CAROLINA
SOUTH CAROLINA
KINGS MOUNTAIN BELT
CHARLOTTE BELT
CAROLINA SLATE BELT
TRIASSIC

southwest where a broad, open, low anomaly covers the eastern end of the study area.

The Kings Mountain belt is marked by elongated anomalies of higher amplitude that have a distinct northeast to southwest trend. This anomaly pattern blends into the pattern of the western Charlotte belt anomalies and terminates in southern Iredell County, North Carolina.

Aeromagnetic map of the study area

Compilation

The aeromagnetic map (Plate 7, 8) is made up of parts of three aeromagnetic surveys (U.S. Geological Survey, 1976a, 1976b, 1978c). The surveys were flown at 500′ altitude along east-west flight lines at 1 mile spacing using a proton precession magnetometer. The data were corrected for the International Geomagnetic Reference Field 1965, and updated to the time of the surveys. Because map intensities varied, isogams were correlated by matching anomalies and reassigning values. The map was then qualitatively examined to relate anomalies and anomaly patterns to specific mapped lithologic units and structural trends.

Description

The aeromagnetic map (Plate 7, 8) contains three magnetic anomaly patterns that are characteristic of the Carolina Slate, Charlotte, and Kings Mountain lithotectonic belts of the Piedmont. The eastern and southeastern part of the study area in Union County, is an area of low magnetic intensity. The intensity here is relatively uniform and undulates above and below the 4300 isogam. A string of extremely elongate, northeast to southwest-trending anomalies occur just east of the Silver Hill fault (Plate 8). Intensity values are slightly higher over the mudstone than over the phyllite. The lowest values of intensity in this area (less than 4200 gammas) are in the south central part of Matthews quadrangle in parallel north to south trending lows. These lows are just east of deeper lows over the Stallings and other granitic intrusions into metavolcanic rocks in the adjoining Charlotte belt and may represent plutons belt plutonic structures under Slate belt metasediments.

A distinct east-sloping gradient in Mint Hill quadrangle separates the Carolina slate belt from the Charlotte belt. This gradient is located where greenschist grade metasedimentary rocks change to amphibolite and higher grade metavolcanic rocks and may reflect the metamorphic change in the rocks. The gradient curves westward and divides west of the negative anomaly over the Stallings granodiorite which straddles the Mecklenburg - Union County line at Stallings, N.C.

The Charlotte belt within the study area is dominated by two large magnetic highs. The largest anomaly occupies the west-central part of the map, and is centered over the Mecklenburg gabbro complex. This positive anomaly has an associated elongate negative anomaly to the north which is common to most magnetic anomalies in the northern hemisphere that are polarized parallel to the earth's magnetic field. A similar positive anomaly is located at the Mecklenburg-Union County line, west of Weddington, N.C., over the Weddington gabbro. The highest intensities (6000 to 7000 gammas) are usually found over olivine gabbronorite.

The north-central part of the Charlotte belt is an area of diverse rock types and high magnetic intensity, consisting of numerous, oval, short wavelength anomalies that give the map a "knotty pine" texture and may reflect the highly varied magnetic character of the rock.

The Mint Hill magnetic anomaly, in eastern Mint Hill quadrangle, is delineated by the closure of the 5000 gamma isogam and occurs over exposures of quartz diorite, quartz schist, felsic metavolcanics, metagranodiorite. A series of SW trending anomalies, also having closures of 5000 gammas in the central Charlotte East quadrangle and a similar trend of anomalies in northeast Mint Hill quadrangle, show a magnetic connection between the Mecklenburg, Mint Hill and the magnetic anomaly over the Concord gabbro of southern Cabarrus County (Bates and Bell, 1965, p. 2).

Anomaly patterns in the western end of the map are similar to those of the north; but the western anomalies are fewer, the shapes are more elongate, and the trends are more distinctly north-south. This is, in part, due to a different style of contouring. The largest anomaly, in this area, is the Mill Creek positive anomaly in southwest Belmont quadrangle which is close to an exposure of gabbro (mgb). Two highs in the Lake Wylie quadrangle appear to be associated with bodies of quartz schist (qs) that are similar to schists from the adjacent King's Mountain belt.

Magnetic summary

The observed anomaly patterns and distributions of intensities (Plate 8) are a direct result of the distribution of magnetic minerals in the rocks, the degree of metamorphic alteration of the magnetic minerals, the magnetic contrast between adjacent rock, and the shape of the subsurface rock body.

(1) In general, magnetic anomalies over the Carolina slate belt have broad wavelengths and probably reflect the magnetic intensities of basement rocks.

(2) A series of elongate anomalies lie east of and parallels the trace of the Silver Hill fault.

(3) The magnetic gradient along the Charlotte-Carolina slate belt boundary may reflect the metamorphic change in the rocks, from greenschist to amphibolite grade.

(4) Mafic and gabbroic rocks usually form positive anomalies and the highest peaks are over olivine gabbronorite.

(5) Northeast trending positive magnetic anomalies in Charlotte East quadrangle suggest a connection between magnetic rocks in Mecklenburg and Concord gabbro plutons.

(6) Magnetic highs in the western part of the map are associated with quartz schist as well as gabbro.

Magnetic properties of rocks of the study area

The magnetic properties of rocks are products of the environment in which they were formed, their composition, and their subsequent structural and geochemical history. Most events that make up the history of a rock leave some imprint on the magnetic signature of that rock. In order to interpret aeromagnetic anomalies effectively, it is necessary to understand the magnetic properties of the underlying rocks that cause the anomalies. In order to arrive at an interpretation, (1) magnetic susceptibility of all samples was measured; (2) magnetic moments of all samples having bulk magnetic susceptibilities of more than 0.9×10^{-3} c.g.s. were measured and NRM (Natural Remanent Magnetism) calculated; and (3) 8 oriented samples were processed to determine the direction of NRM polarization. The data gathered were then used to investigate the relationship between induced and remanent magnetism in some of the rocks of southern Mecklenburg County and vicinity, and also to interpret the aeromagnetic anomalies. Magnetic

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Table 2. Physical properties of Carolina slate belt rocks from southern Mecklenburg County and vicinity.

Table 2. Physical properties of Carolina slate belt rocks from southern Mecklenburg County and vicinity.

Rock type	Density g/cc			Mag. Sus. x 10^{-3} c.g.s.			NRM x 10^{-3} c.g.s.		
	AV	Range	N	AV	Range	N	AV	Range	N
Tillery Formation									
phyllite	2.69	2.73-2.63	3	0.010	0.010	1			
metavolcanics									
felsic	2.73	2.81-2.63	3	0.035	0.012-0.061	3			
mafic	2.83	2.94-2.79	7	0.050	0.046-0.055	6			
Intrusives									
mafic	2.97	3.01-2.94	2	0.065	0.065-0.055	2			

AV = Average, N = Number of samples

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Table 3. Physical properties of Charlotte belt rocks from southern Mecklenburg County and vicinity.

Table 3. Physical properties of Charlotte belt rocks from southern Mecklenburg County and vicinity

Rock type	Density AV	g/cc Range	N	Mag. Sus. AV	x 10^{-3}c.g.s. Range	N	NRM x AV	10^{-3}c.g.s. Range	N
Old Plutonic supergroup									
plutons	2.69	2.55-2.94	13	1.246	0.97- 3.667	13	0.233	0.063-0.470	6
Concord-Salisbury supergroup									
Mecklenburg hornblende gabbro	2.94	2.83-3.10	16	8.770	2.248-13.008	16	0.702	0.188-1.746	17
Weddington gabbro	2.89	2.81-2.97	18	3.830	0.750- 6.960	18	7.681	0.335-27.493	16
Mecklenburg hornfels	2.84		1	0.720					
Weddington hornfels	2.96		1	0.098					
Eagle Lake granodiorite	2.70	2.69-2.71	2	2.977	2.845-3.11	2	0.666	0.030-1.30	2
Providence Church monzonite-syenite	2.65	2.63-2.71	4	2.040	.010-4.169	4	0.955	0.708-2.128	3
Stallings granodiorite	2.64	2.61-2.64	3	0.050	0.074-0.126	3			
Landis supergroup									
Weddington granite	2.61	2.61-2.62	2	1.146	0.884-1.408	2	0.296		1
Other rocks									
metavolcanics									
felsic	2.69	2.59-2.77	5	0.401	0.267-0.657	4			
mafic	2.96	2.91-2.99	4	2.330	0.069-4.95	4			
intermediate	2.83	2.75-2.96	3	2.210	1.310-2.663	3	0.204	0.045-0.345	
biotite gneisse	2.62	2.62-2.63		0.541	0.540-0.57		0.890	0.069-.109	
quartz schist	2.62			0 006					
amphibolite	2.89	2.75-2.98	5	2.182	0.137-9.334	5	0.590	0.589-0.591	2

AV = Average, N = Number of samples

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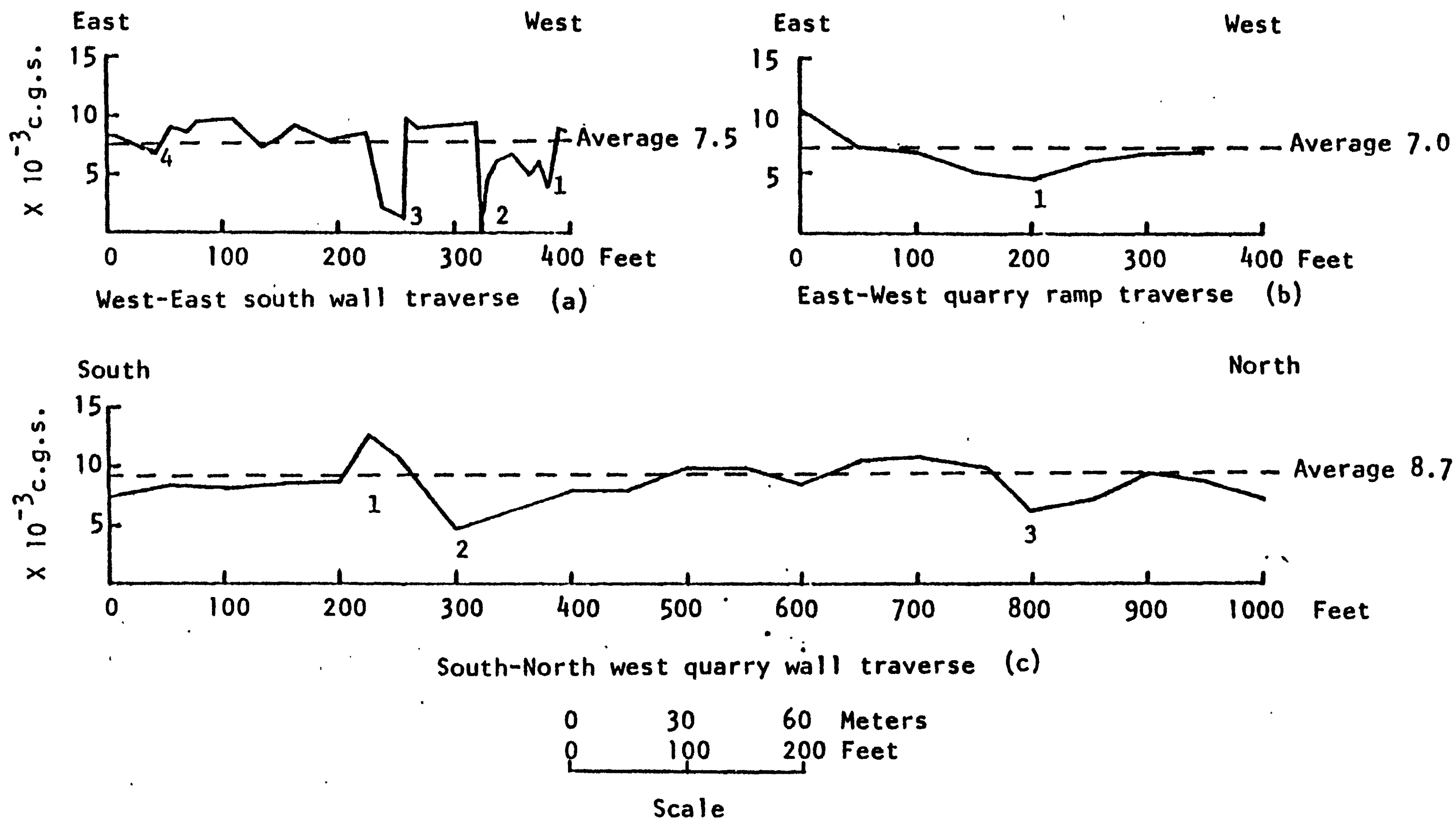
Figure 10 Magnetic susceptibility measurements of hornblende gabbro in the Arrowood quarry, Charlotte, North Carolina.


East
West
X 10^{-3}c.g.s.
15
10
5
0
100
200
300
400 Feet
Average 7.5
1
2
3
4
West-East south wall traverse (a)
East
West
15
10
5
0
100
200
300
400 Feet
Average 7.0
1
East-West quarry ramp traverse (b)
South
North
X 10^{-3}c.g.s.
15
10
5
0
100
200
300
400
500
600
700
800
900
1000 Feet
Average 8.7
1
2
3
South-North west quarry wall traverse (c)
0 30 60 Meters
0 100 200 Feet
Scale

and density data are listed in Table 2 and Appendix B.

Magnetic susceptibility

The Bison Magnetic Susceptibility Meter (Model 3101) measures the magnetic susceptibility of rocks within the range of 0.0001 to 0.1 cgs (1.256 x 10^{-4} to 1.256 SI units). This meter was used to determine the magnetic susceptibility of 162 rock samples (see Appendix D) and to make 58 in situ field measurements on hornblende gabbro along east-west and north-south traverses, on the south and west walls of the Arrowood rock quarry Charlotte, N.C. (see fig. 10).

Quarry traverses

The Arrowood quarry is located east of route 77, just north of the South Carolina state line, in northeast Fort Mill quadrangle. Measurements were made (c) at 15.2 m (50 feet) intervals along a south-north traverse of the west wall of the quarry; (b) a west-east traverse of the south wall of a ramp in the lower quarry; and (a) at irregular intervals along the south wall of the lower quarry. The results are plotted in Figure 10 and show several sharp dips in magnetic susceptibility.

West-east traverse, south wall of quarry (a)

1. Dips are attributed to crushed rock near an east-west strike-slip fault at the 400 foot mark. The fault caused a displacement of 4 feet on a felsic dike.

2. The sharp dip at 99 m (325 feet) is caused by 1.3 m (4 feet) wide, felsic dike that strikes N-S, and dips 50^{o} east.

3. The wide dip at 76 m (250 feet) is a lens of coarse porphyritic hornblende gabbro 3 m (9 feet) thick with large feldspar phenocrysts.

4. The dip at 8 m (25 feet) is a shear zone 2 to 3 m wide which also dips 50° east.

East-west traverse, quarry ramp (b)

1. Low values occur at 61 m (200 feet) and correlate with an increase in grain size.

The north-south traverse, west quarry wall (c)

1. A high peak occurs at an aphanitic mafic dike which also has a high NRM moment (see fig. 13).

2. The dip in susceptibility north of the dike is caused by a large pegmatite.

3. The dip in susceptibility at 244 m (800 feet), is probably due to a coating of dripstone on the rock surface.

The average magnetic susceptibility of the hornblende gabbro in the quarry is 8.2×10^{-3} c.g.s. and 7.3×10^{-3} c.g.s. from laboratory measurements. The field measurements include the effects of dikes, inclusions, and fractures and are probably more representative of the hornblende gabbro. The profile variations, however, are not reflected in the aeromagnetic anomaly that is measured 152 m (500 feet) above the ground surface. The quarry lies at the southern end of a crescent-shaped 6200 gamma aeromagnetic anomaly that is probably associated with the nearby Dinkins Cemetary gabbro and a north-south linear low 0.5 km west of the quarry which may reflect the north-south shear and felsic dike.

Remanent magnetism

A spinner magnetometer designed and described by Doell and Cox (1965) was used to measure the remanent magnetic intensity of 73 samples and the direction of NRM in 8 oriented samples (fig. 11). This magnetometer is capable of measuring remanent magnetization in the range

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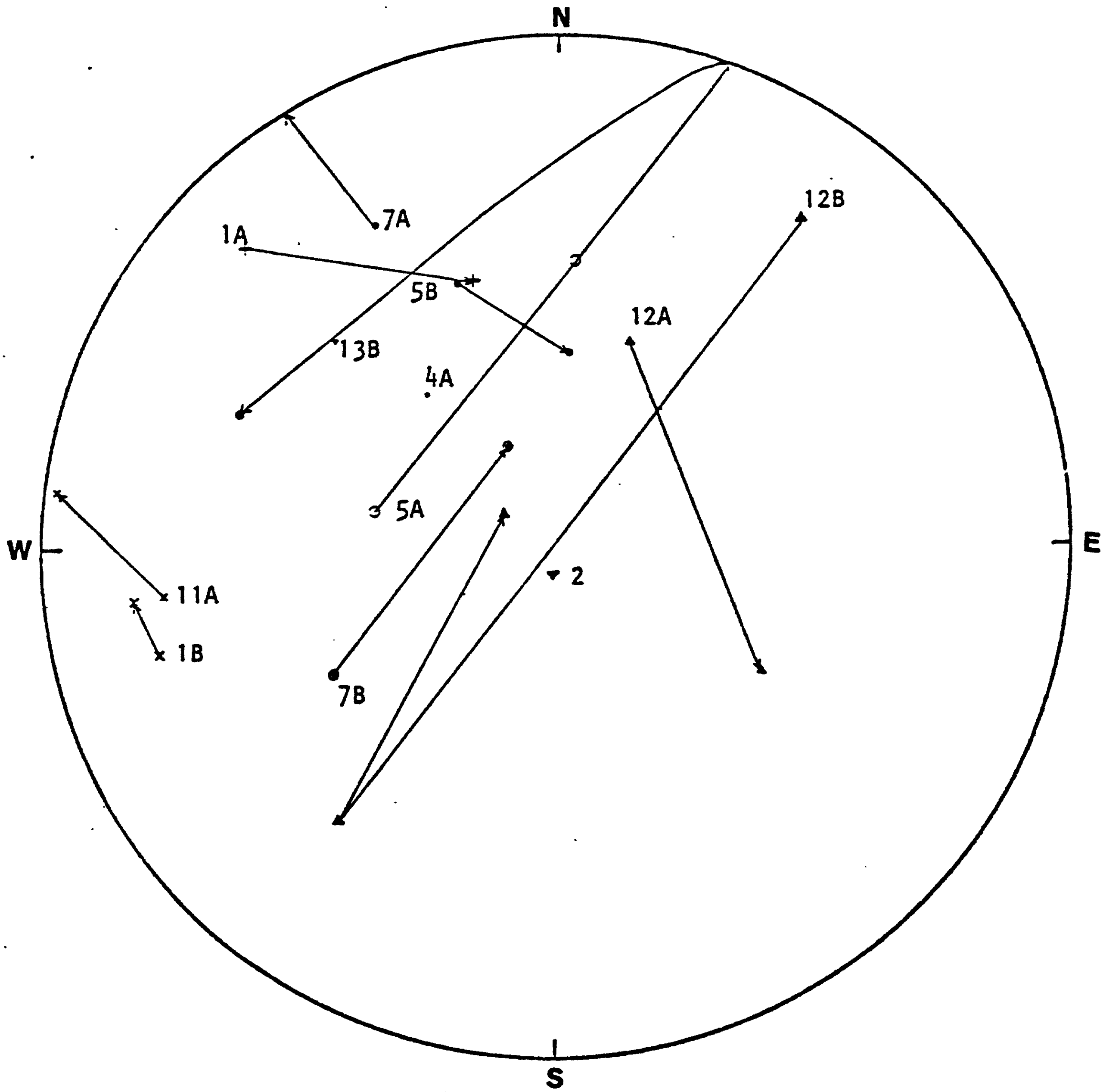
Figure 11. Diagram of magnetic pole migrations in "uncleaned" hornblende gabbro samples from the Arrowood quarry, Charlotte, North Carolina.


N
S
W
E
7A
1A
5B
13B
4A
12B
12A
5A
11A
1B
7B
2

of 10^{-5} to 1.0 emu/cc with an accuracy of 1 degree of vector and several percent intensity. Each sample was spun and the magnetic intensity calculated according to Doell and Cox (1965).

Oriented samples

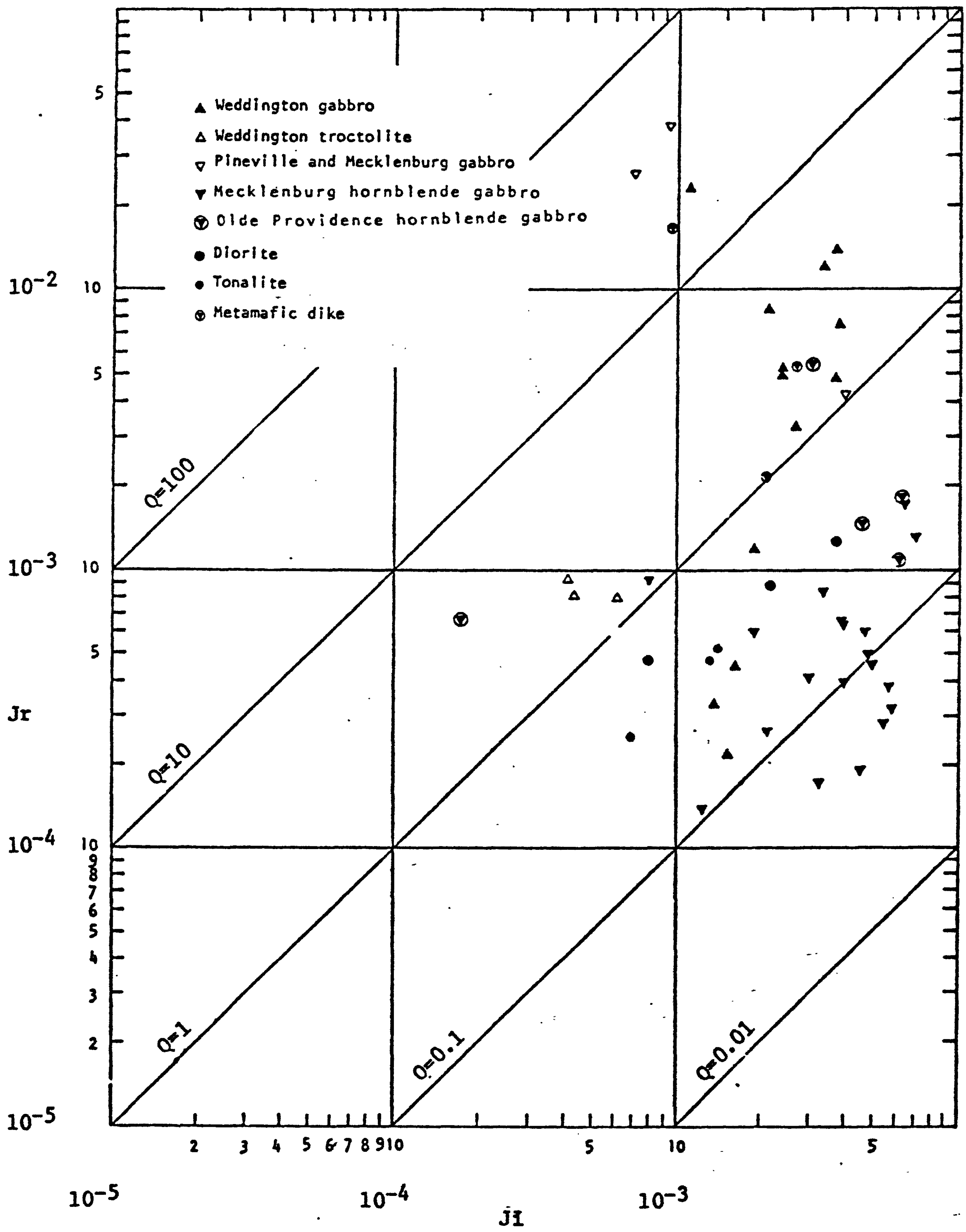
Eight oriented samples of hornblende gabbro of the Mecklenburg complex were collected from east-west and north-south magnetic traverses in the Arrowood quarry to provide some indication of the directon of NRM. Each oriented core was spun in the magnetometer and the vector was plotted on an equal area net (fig. 11) according to the method described in Doell and Cox (1956). The oriented samples were not magnetically cleaned and changed direction on subsequent spins (fig. 11). This change in direction indicates that the hornblende gabbro has a large component of Viscous Remanent Magnetism (VRM).

Jr, Ji, Q Plot

The NRM (Jr), induced magnetizaton (Ji), and Q values of some samples are plotted on logarithmic graph paper in Figures 12 and 13. These diagrams clearly show distinct groups of rock samples. The gabbros have the highest Q values, the highest Jr, and are in the upper portion of the plot.

The Pineville olivine gabbronorite samples have the highest Q values, and Ji intermediate between the troctolite and olivine gabbronorite of the Weddington gabbro (fig. 12). The high component of magnetization may explain the aeromagnetic peak of 7300 gammas over exposures of Pineville gabbronorite and the peaks over other gabbronorite exposures. If the direction of the NRM vector was completely opposite to the present earth's field, substantial amounts of this rock could cause a large negative anomaly. Since the anomaly is

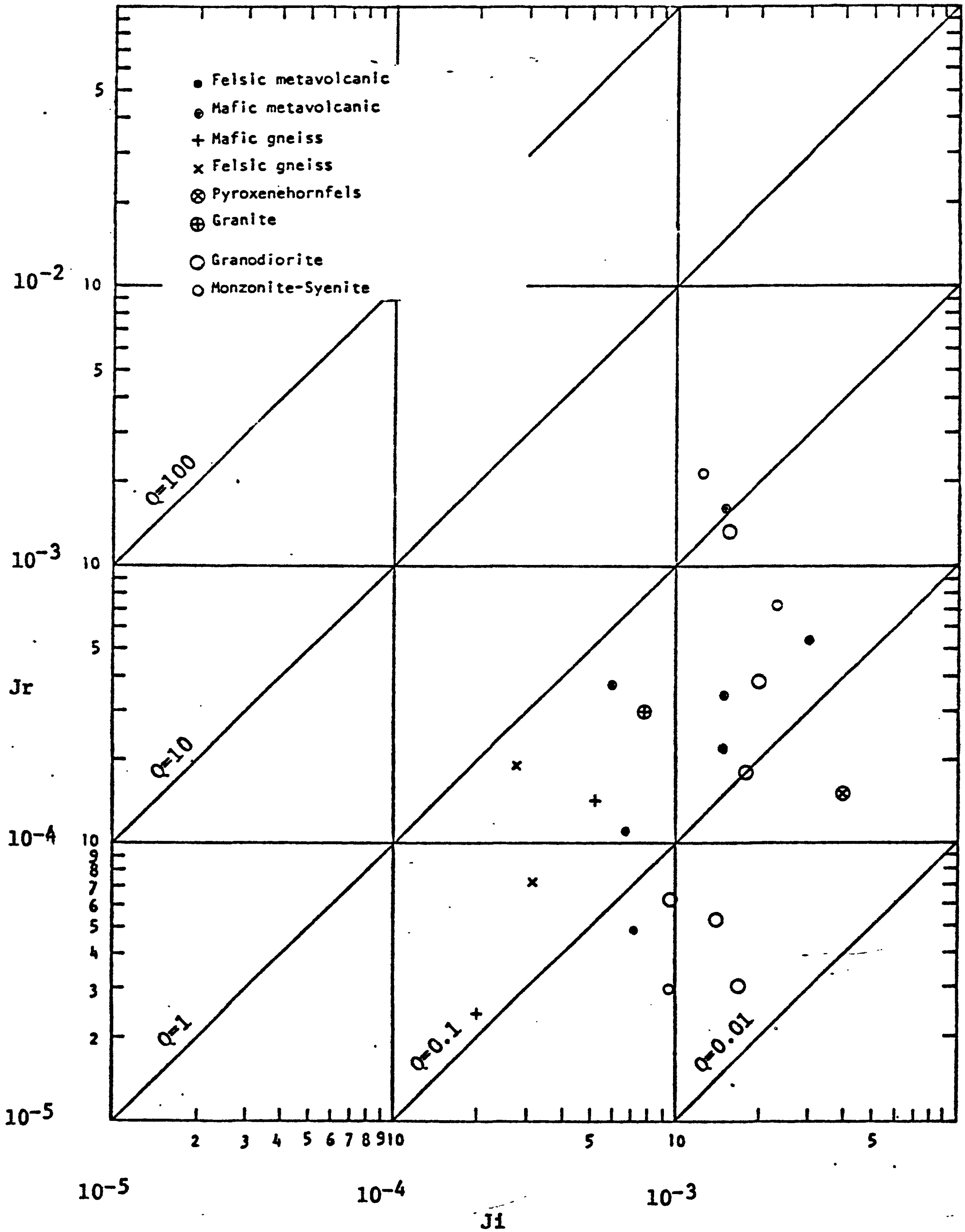
Figure 12. Jr-Ji-Q Plot of gabbro, diorite, tonalite, and mafic dike rock samples.



▲ Weddington gabbro
△ Weddington troctolite
▽ Pineville and Mecklenburg gabbro
▼ Mecklenburg hornblende gabbro
Olde Providence hornblende gabbro
● Diorite
• Tonalite
Metamafic dike
Q=100
Q=10
Q=1
Q=0.1
Q=0.01
Jr
Jl
10^{-2}
10^{-3}
10^{-4}
10^{-5}

61

Figure 13. Jr-Ji-Q Plot of metavolcanics, gneiss, hornfels, and granitic plutonic rock samples.


Felsic metavolcanic
Mafic metavolcanic
Mafic gneiss
Felsic gneiss
Pyroxenehornfels
Granite
Granodiorite
Monzonite-Syenite
Q=100
Q=10
Q=1
Q=0.1
Q=0.01
Jr
Ji
10-2
10-3
10-4
10-5
10-5
10-4
10-3

positive, we can assume that the direction of NRM is approximately parallel to the present earth's field and adds to it, thereby producing the high intensity.

Both the Weddington troctolite and olivine gabbronorite samples, have the same Q values which are greater than 1.0, but, the troctolite samples have lower Ji and Jr, and form a separate group from the olivine gabbronorite samples. Samples of olivine gabbronorite from locations W1003 and W1002 have a more varied range of Jr which may reflect variations in texture of the samples. The textures range from equigranular to poikilitic at these locations, which may be near the edge of the gabbro pluton. The peak in intensity of the aeromagnetic anomaly over exposures of Weddington gabbronorite is attributed to the higher Jr and Ji of these rocks.

The Mecklenburg hornblende gabbro samples are grouped between Ji 2.0×10^{-3} c.g.s. - 3.0×10^{-3} c.g.s., and around the Q=0.1 line. The NRM of this body is also probably aligned in the general direction of the earth's present field, and is added to the induced magnetic field around the gabbro. The large negative anomaly on the north side of the Mecklenburg gabbro suggests that this is so. The Olde Providence hornblende gabbro samples (W213A, W213B, W466B) group in a very small area (fig. 12).

The diorites, tonalites, hornblende gabbros, and some granodiorites of the Old Plutonic complex generally plot between Q=0.1 and the Q=1.0. The granodiorites in this field all exhibit some degree of weathering which may have altered the magnetic minerals.

Most of the granitic rocks, felsic metavolcanics, and gneisses (fig. 13) fall into the lower end of the plot about Q=0.1. The mafic metavolcanic samples (CW1111B, CE166, LW279D, MA876C, and MA876B) plot close to Q=0.1 and the intermediate metavolcanics plot at lower Q ratios similar to felsic metavolcanics samples.

GRAVITY

Introduction

The gravity methods used in this study include field measurements, data reduction, compilation, and interpretation of the resulting gravity maps. Gravity anomalies are related to density variations within the earth and can be used to estimate the depth and shape of subsurface geologic structures which exhibit density contrast.

Gravity Survey

The gravity survey covers 10 U.S. Geological Survey 7 1/2′ quadrangle maps (see Plate 9,10). Gravity measurements were made with LaCoste and Romberg gravimeter No. 159 during 1977 as part of the Charlotte 2 degree sheet gravity survey; and 675 gravity stations, about one station per 2 km^2, were established in the study area. Each day's measurements were tied to a series of local base stations. The base stations were, in turn, tied to the National Gravity Network Station "Charlotte A" (Department of Defense Reference no. 2096-1, Defense Mapping Agency, 1970) at the University of North Carolina at Charlotte. This station has a value of 979728.06 milligals (adjusted to the 1971 International Gravity standardization datum, Morelli, 1974).

Surveyed elevations at road intersections obtained from U.S. Geological Survey 7 1/2′ topographic maps and bench marks provided the bulk of the elevation control for most of the survey. Elevations at road intersections have an estimated accuracy of 0.3 m (1 foot) and result in a possible maximum Bouguer error of 0.06 milligals due to such elevation uncertainty.

Field measurements were reduced by computer using U.S. Geological Survey gravity reduction program W9204, written by Paul Zabel and W. Minor Davis, and modified by David Daniels and the author, which corrects for earth tides and instrument drift. Latitude corrections are based on the 1967 International Gravity Formula (International Association of Geodesy, 1971), $g = 978.03185 (1+.005278895 \sin^2 L+.000023462 \sin^4 L)$ gal, where L = latitude. Bouguer correction density 2.67 gm/cc was used on all stations. No terrain corrections were made because the topography is relatively flat. It is estimated that uncorrected terrain errors should be less than 0.02 mg.

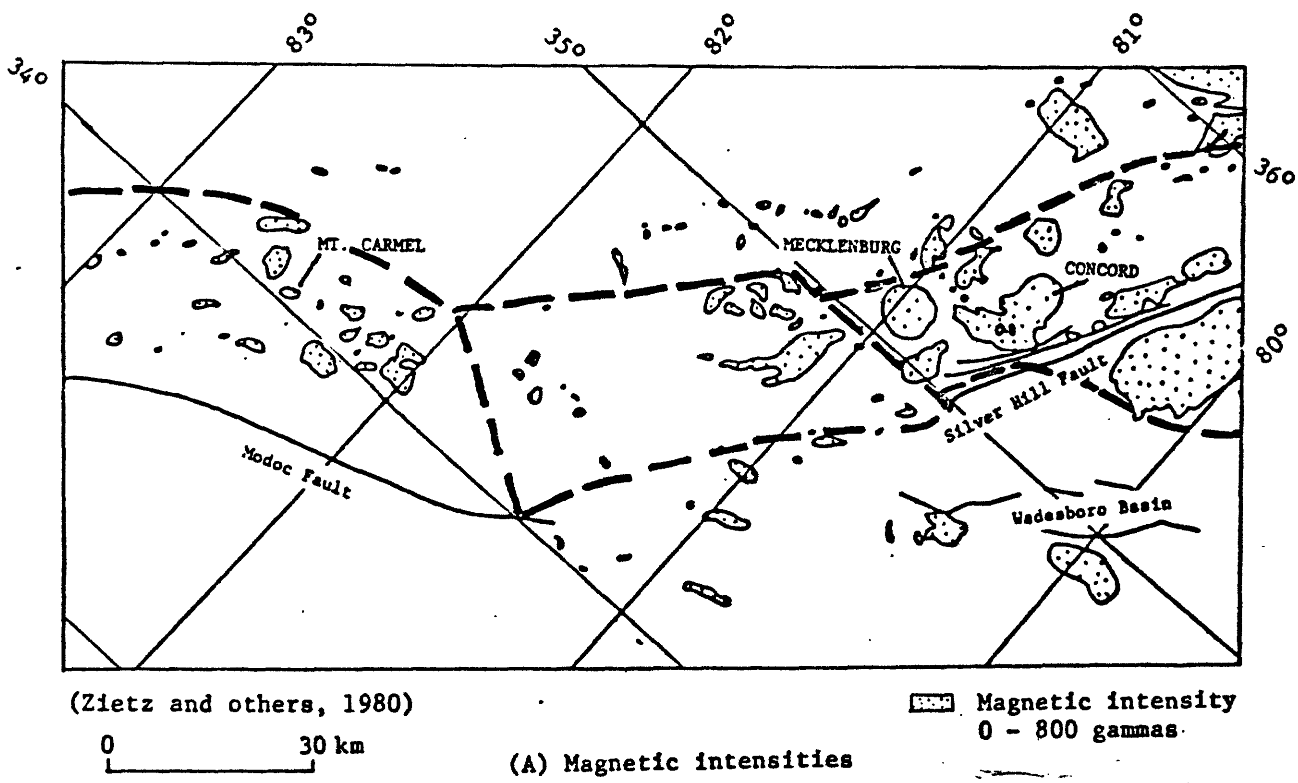
Regional gravity setting

The gravity field of the study area is affected by a strong west-dipping gradient that extends from Newfoundland to Alabama along the Appalachian orogen (Haworth and others, 1981; Haworth, 1978) (fig. 14(B)). The simple Bouguer gravity map of the Charlotte 1 x 2 degree quadrangle (Wilson and Daniels, 1980) (fig. 15) shows the gravity field in the immediate vicinity of the study area and its relationship to the regional geology. Distinct anomaly patterns are correlated with Piedmont lithotectonic belts and reflect their structural styles. The study area is located in the south central part of this map.

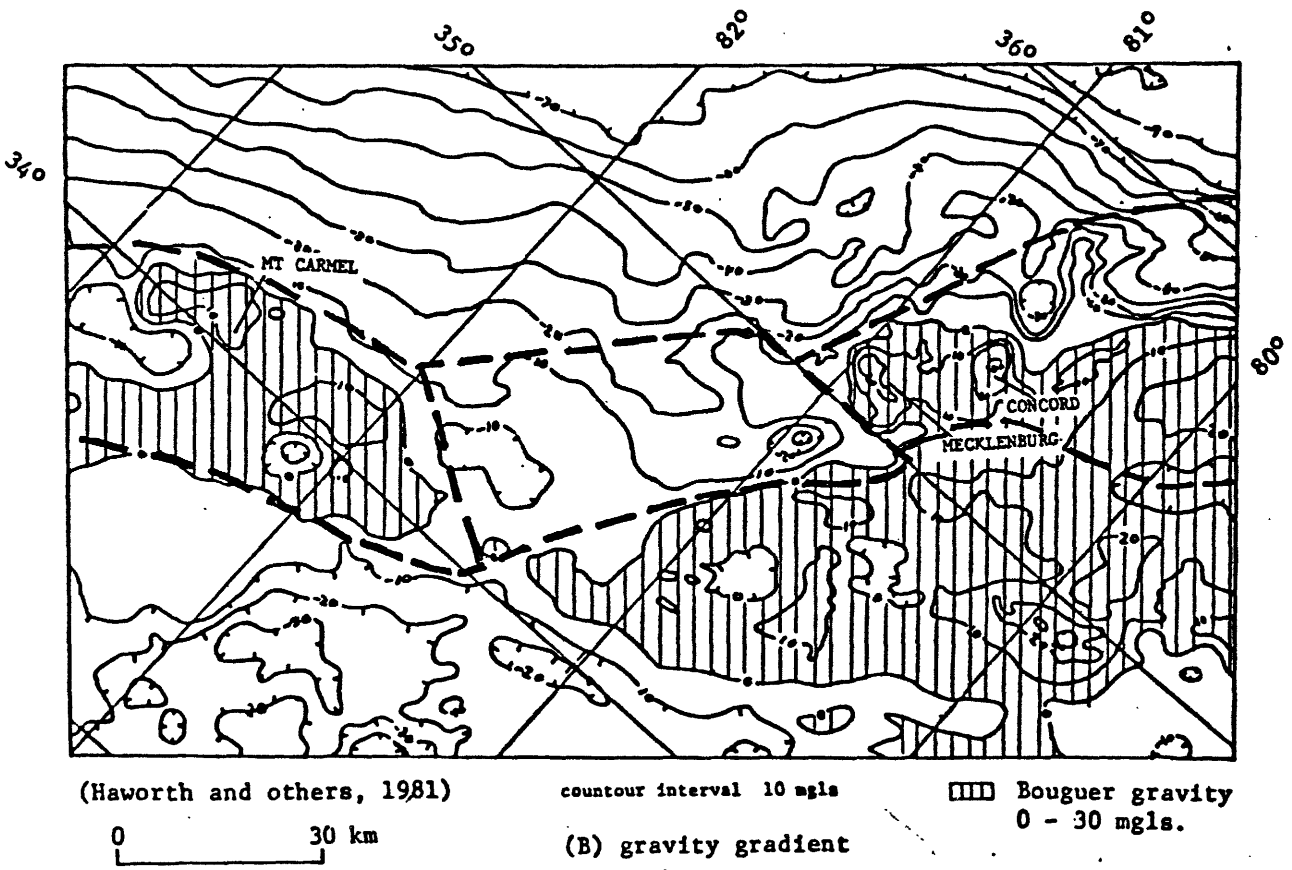
The Carolina slate belt contains a long low anomaly, which open to the south and parallels the Charlotte-slate belt boundary. This anomaly extends into the eastern end of the study area. The Charlotte belt is characterized by circular to oval, high and low amplitude anomalies.

The Kings Mountain belt contains a series of northeast to southwest trending, paired, elongated, positive and negative anomalies. Between the Charlotte belt and Kings Mountain belt is a north to south trending west-dipping gradient that includes the western part of the study area.

Figure 14. Regional Appalachian magnetic intensity, after Zietz and others (1980) (A) and gravity gradient, after Haworth and others (1981) (B) in the Carolina Piedmont.



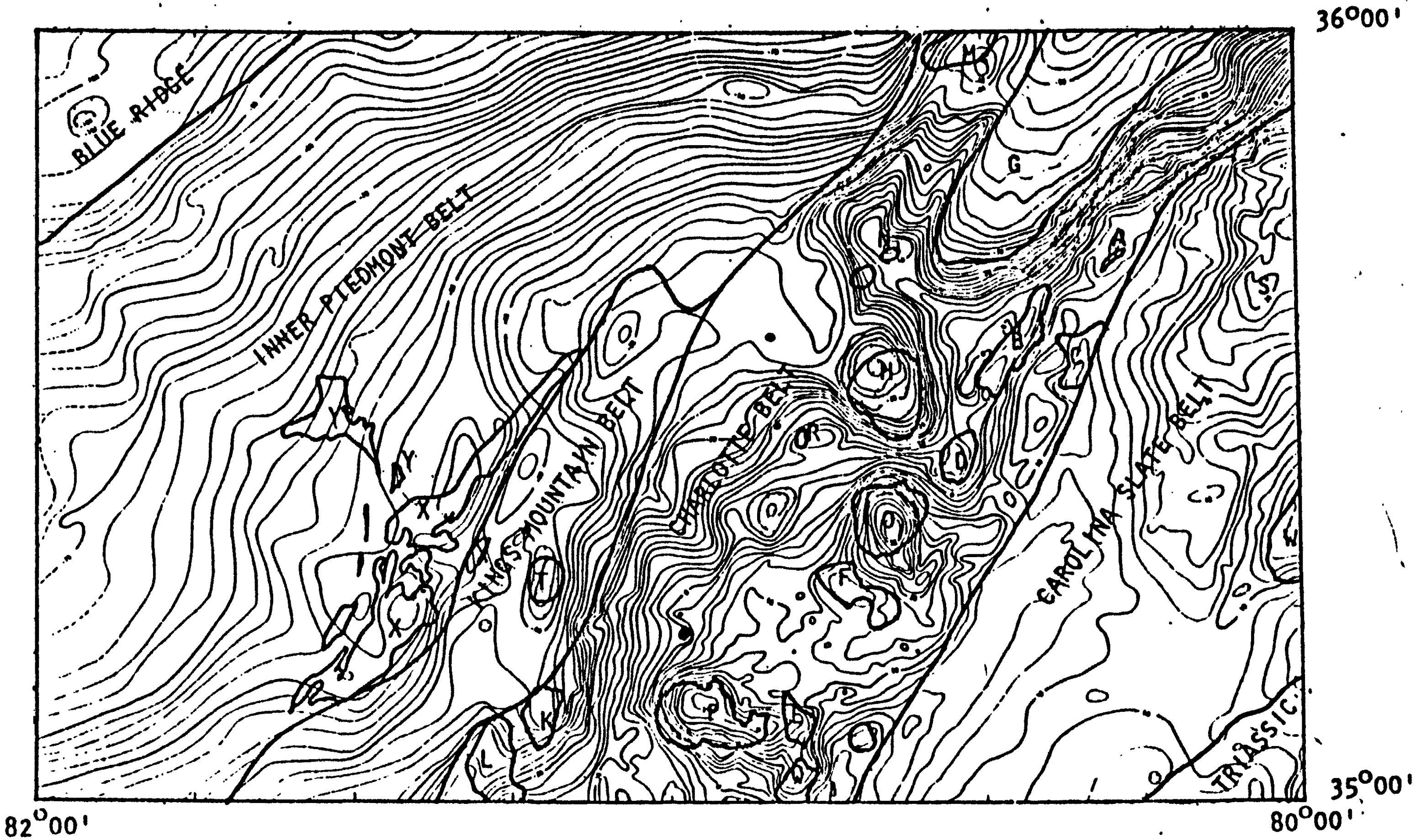
(A) Magnetic intensities



(B) gravity gradient

Charlotte belt composite batholith and segments (surface and subsurface).

Figure 15. Generalized geology and Piedmont belt boundaries modified from Goldsmith and others (1978) for the Charlotte 2^{o} sheet showing simple Bouguer contour of Wilson and Daniels (1980).


36°00'
BLUE RIDGE
INNER PIEDMONT BELT
KINGS MOUNTAIN BELT
CHARLOTTE BELT
CAROLINA SLATE BELT
TRIASSIC
35°00'
82°00'
80°00'

Generalized geology of the Charlotte belt

Concord-Salisbury group granitic plutons (413-386 m.y.)

A Southmount

B Salisbury

C Gold Hill

D Not named

E Stallings

Concord-Salisbury gabbro complexes

M Farmington

N Bear Poplar

O Concord

P Mecklenburg

Q Weddington

R Cornelius (partly unroofed)

Landis granitic plutons (325-265 m.y.)

G Churchland

H Landis

I Huntersville (subsurface)

J Berryhill (subsurface)

K Clover

L York

T Gaston

Other granitoid plutons

X Cherryville

Y Toluca

Structures

W Troy anticline

S Subsurface mafic mass

Simple Bouguer gravity map of the study area

Compilation

The reduced gravity survey data were contoured on transparent mylar at a 2 mgl contour interval and a scale of 1:62,500. This map (Plate 9, 10) was in turn overlain on a similar scale geologic map of the area, and correlations with lithologies and structures were studied. The gravity map along with other geophysical data was used to aid geologic mapping and also to model geologic structures.

Description

The simple Bouguer gravity map of the study area (Plates 9 and 10,) contains linear low amplitude anomalies in the slate belt; circular anomalies in the Charlotte belt; and that part of the gradient lying between the Charlotte belt and Kings Mountain belt. The eastern end of the map is marked by a northeast to southwest trending gravity trough over Slate belt rocks. In the central part of the trough, there is a small, low-amplitude (4 milligal) high which may be associated with a series of mafic intrusives; a series of lows along the Slate and Charlotte belt boundary at Stallings and east of Weddington are over granitic plutons; and a distinct northeast-southwest gradient extends from the northeast corner of the map along the Charlotte-Carolina slate belt boundary and continues along the western edge of the low at Stallings. The gradient bifurcates southwest of the Stallings granodiorite low. One branch continues south along the east edge of the Weddington gabbro high. The other branch separates the Olde Providence and Weddington gabbro anomalies and continues into Fort Mill quadrangle. These gradients form the edge of a broad gravity plateau in the Charlotte belt. The southern end of the plateau contains 2 highs reaching the +24 milligal isogal over the Mecklenburg gabbro and the +16 milligal isogal over the Weddington gabbro. In northern Mint Hill and Midland quadrangles, the east-west trending Mint Hill gravity anomaly joins positive anomalies (16 isogal) over gabbro which trend south from the Concord gabbro. A short wavelength low is located at the western edge of the gravity plateau at Berryhill in northwestern Charlotte West quadrangle and is located over quartz schist and tonalite. An east-west linear feature, marked by eastward deflections of the 0 and 10 milligal contours, seems to extend east from the Berryhill low, across the northern part of the map, and north of the high in Mint Hill and Midland quadrangle.

The western edge of the map is occupied by a west-dipping gradient, with minor irregularities in the west and north. This gradient is associated with Old Plutonic complex, metavolcanics, and quartz schist. In the southwest, north-south trending low anomalies predominate.

These anomaly patterns reflect the structural style and lithologies in the Piedmont belts found in the map area.

Summary of gravity

The distinctive gravity anomaly patterns reflect the distribution of densities of the underlying rocks. Generally, high or positive anomalies indicate mafic rocks and low or negative anomalies granitic rocks.

(1) The Charlotte-Carolina slate belt boundary is marked by a gravity gradient which bifurcates west of Stallings and continues north and east of the Weddington gabbro.

(2) The Mecklenburg-Weddington complex occurs at the end of a gravity high which extends to the Mint Hill gravity anomaly and the gabbros of the Concord complex.

(3) The Berryhill gravity low is not associated with any exposed granitoid rock and may indicate a subsurface pluton.

GEOPHYSICAL INTERPRETATONS

The Mecklenburg-Weddington Gabbro Complex

The Mecklenburg-Weddington gabbro complex (Plates 1 and 2) is one of the largest and best known gabbro plutonic complexes in the Charlotte belt. It occupies the central part of the study area and its presence is manifested by distinctive soils, topography, and major radioactivity, magnetic, and gravity anomalies.

Because exposures are rare in this region, contacts are rarely seen. It is useful, therefore, to compare the mapped geologic and soils' contacts of the Mecklenburg-Weddington complex with the contacts indicated by each of the geophysical methods. The geophysical contacts of the Mecklenburg-Weddington gabbro (figs. 16, 17) were constructed by connecting the midpoints of the steepest gradients between high and low anomalies around the periphery of the complex. Soils' contacts are from Hearn and Brinkley (1912) and geologic contacts from Plate 1. The interpreted radioactivity contacts (fig. 16) coincide very closely with the soils' and geologic contacts. All data bases suggest that the western complex is a circular exposure of mafic rock 11 km in diameter which is connected to an elongate eastern exposure of mafic rock also 11 km long. The Weddington gabbro is separated from the eastern complex by a narrow arcuate band of high radioactivity (Plate 6), that is probably caused by potassium-rich igneous rock.

Figure 16. An interpretive map of the Mecklenburg-Weddington gabbro complex showing mafic soils, geologic contacts, and radioactivity gradients.

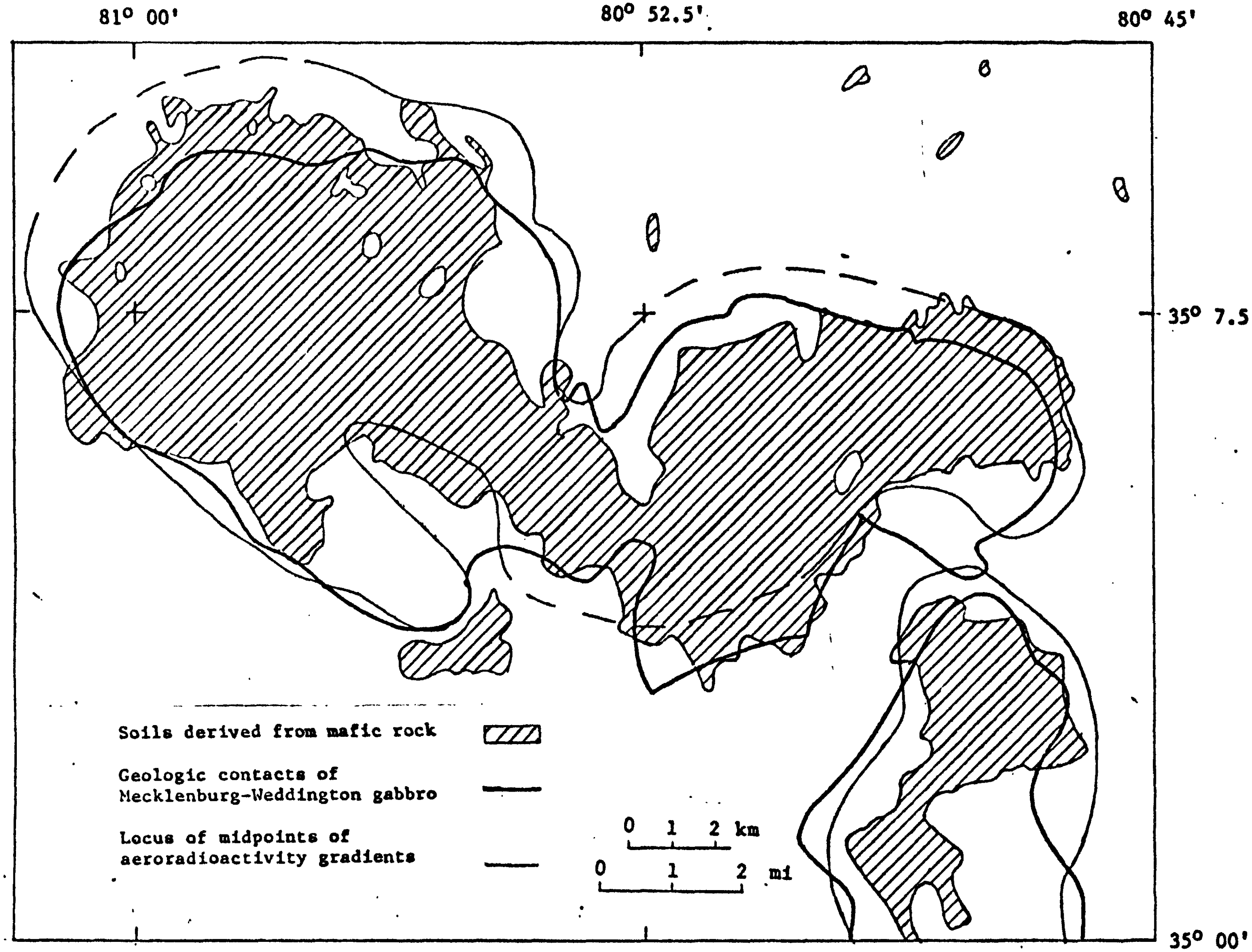
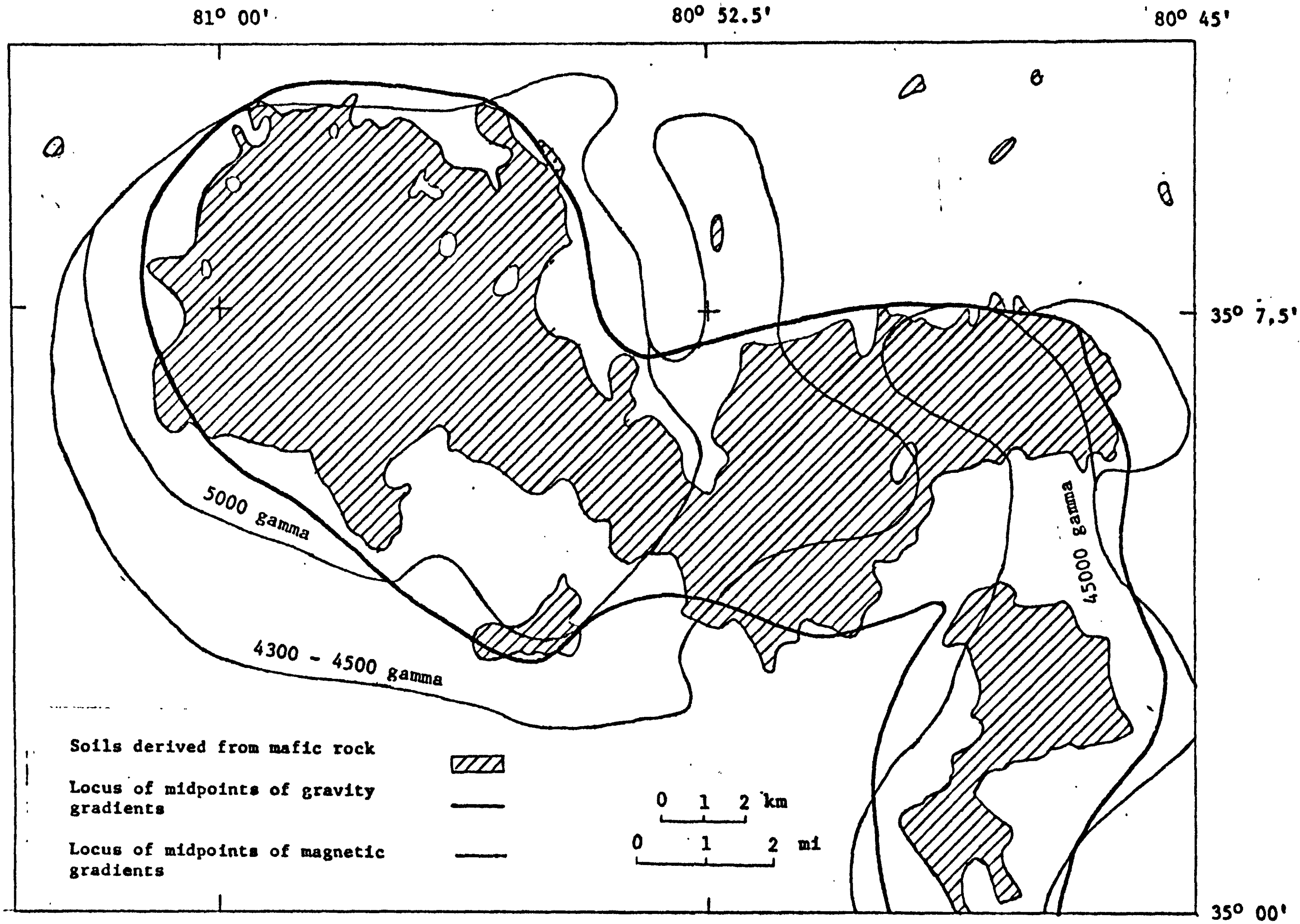

81° 00'
80° 52.5'
80° 45'
35° 7.5'
35° 00'
Soils derived from mafic rock
Geologic contacts of
Mecklenburg-Weddington gabbro
Locus of midpoints of
aeroradioactivity gradients
0 1 2 km
0 1 2 mi

Figure 17. An interpretive map of the Mecklenburg-Weddington gabbro complex showing mafic soils, and gravity and magnetic gradients.


81° 00'
80° 52.5'
80° 45'
35° 7.5'
35° 00'
5000 gamma
4300 - 4500 gamma
45000 gamma
Soils derived from mafic rock
Locus of midpoints of gravity gradients
Locus of midpoints of magnetic gradients
0 1 2 km
0 1 2 mi

Structure

The gravity and magnetic fields provide information on the subsurface structure of the gabbro bodies (figure 17, Plates 7, 9). The shape of the gravity anomaly over the complex closely conforms to outlines suggested by the soil and geologic maps of the gabbros indicating that the main mass of the rock is confined to these boundaries; but the magnetic anomalies, especially in the southern area of the western complex, extend far beyond the surface outcrop pattern.

The western complex is circled by two magnetic gradients. One gradient, at about 5000 gammas, often coincides with radioactivity gradients and geologic contacts. The 5000 gamma gradient denotes the surface contact of the gabbro. Another gradient, at about 4300 to 4500 gammas extends much further south than the main gravity and magnetic anomalies and may be caused by a thin subsurface sill-like structure which does not have enough mass to influence the shape of the gravity anomaly. On the other hand, as the gravity contours in this area show no relationship to the magnetic contours, the second magnetic gradient may be related to subsurface hornfels in the country rock produced by metamorphic or metasomatic processes.

The magnetic anomaly over the Olde Providence metavolcanics and the northeast end of the Weddington magnetic anomaly likewise extend beyond the gravity gradient midpoint, and suggest that these magnetic anomalies may be due either to thin sills or to contact phenomena.

The Weddington magnetic anomaly has a very steep gradient along its southeast edge coinciding with steep radioactivity and gravity gradients. These steep geophysical gradients suggest a sharp contact extending to considerable depth and provide possible evidence of the Gold Hill fault. The Weddington gravity anomaly maximum (16 milligals) is 2 km north of the magnetic center. There is less than a 2 milligal separation between the Weddington anomaly and the Olde Providence gravity anomaly. These magnetic and gravity features suggest that the body is a sill-like structure about 1.5 km thick, assuming a density contrast of 0.26, (g = 41.93 x density contrast x thickness; Nettleton, 1976, p. 193) which dips to the north to join the Olde Providence gabbro.

Steep Mecklenburg gravity gradients indicate bodies with steeply dipping sides. The western and southern sides of the combined anomaly have gradients that range from a low of 0 to a high of +24 milligals indicating contacts with low density granitic rock. But the northern side of the anomaly merges with the 12 milligal high north of the complex, probably caused by dense mafic rock that may be connected with the gabbro complex.

A gravity high extends north and northeast from the Mecklenburg complex in Charlotte East quadrangle toward the Mint Hill gravity high. The high follows the trend of a series of small high magnetic anomalies and some occurrences of Iredell soils indicating the presence of near-surface mafic rock. This trend also suggests that the mafic rock forms a direct connection with the subsurface rock at Mint Hill and exposures of gabbro in Cabbarus County which extend south from the Concord gabbro.

Mecklenburg gravity model

The model of the Mecklenburg gabbro was constructed to match gravity profiles, A,A′ and B,B′ (Plate 9 and 10, figures 18 and 19) using the Talwani 2 dimensional computer program to calculate gravitational attraction. The observed profiles are parallel to the strike of the regional gravity gradient near the 0 isogal. Hornblende gabbro samples have an average density of 2.94 g/cc, olivine gabbronorite has an average density of 2.89 g/cc, and granodiorite north and south of the gabbro has an average density of 2.66 g/cc. These density contrasts of 0.28 g/cc and 0.23 g/cc yield a theoretical thickness for the body of 3.5 to 4.5 km.

Such a body may be a lopolith and the north side is a sill-like structure about 2 km thick which extends northward and may cause the broad gravity high in the northern Charlotte belt. This mass of mafic rock could be in the form of sheets, dikes, or multiple sills and not necessarily in the form of a single sill as shown. These thinner sheets and sills may metamorphose more readily and form some of the metagabbroic rocks which outcrop in Charlotte East and Charlotte West quadrangles. The sill is projected toward the surface wherever positive gravity and magnetic anomalies, Iredell soils, and mapped geology indicate mafic rocks at the surface.

The northeast trending mafic masses between the Concord and Mecklenburg-Weddington complexes are probaly directly related to the emplacement of these two large mafic bodies, because: (1) each of the complexes forms a large high amplitude gravity anomaly outlined by the 0 isogal (fig. 14(A) and 15), (2) later Mesozoic intrusive could not be the cause because Mesozoic diabase dikes, clearly indicated by linear magnetic anomalies in the southeastern Carolina slate belt of figure 9, show northwesterly trends, and (3) a thick roof pendent of mafic volcanic rock in the Old Plutonic complex, capable of producing a 12 milligal anomaly, is improbable because frequent outcrops of plutonic rock interspersed throughout areas of volcanic rock, indicate that the volcanic rock is thin.

The sharply different directional trends of the Mecklenburg-

Weddington plutons suggests that a major regional fault or fracture system controlled emplacement of the gabbros. The Mecklenburg and Olde Providence plutons form a distinct east-west trend that cuts across the regional northeast-southwest gravity and magnetic trends. The Weddington plutons, located at the eastern end of this trend, however, follow the northeast-southwest regional trend. This outcrop pattern of linear east-west cross-cutting gabbro plutons plus smaller southwest trending gabbro bodies close to the Slate belt boundary, is similar to that of the Concord gabbros to the north which Bates and Bell (1965) suggested were emplaced along northeast-southwest and northwest-southeast fracture systems.

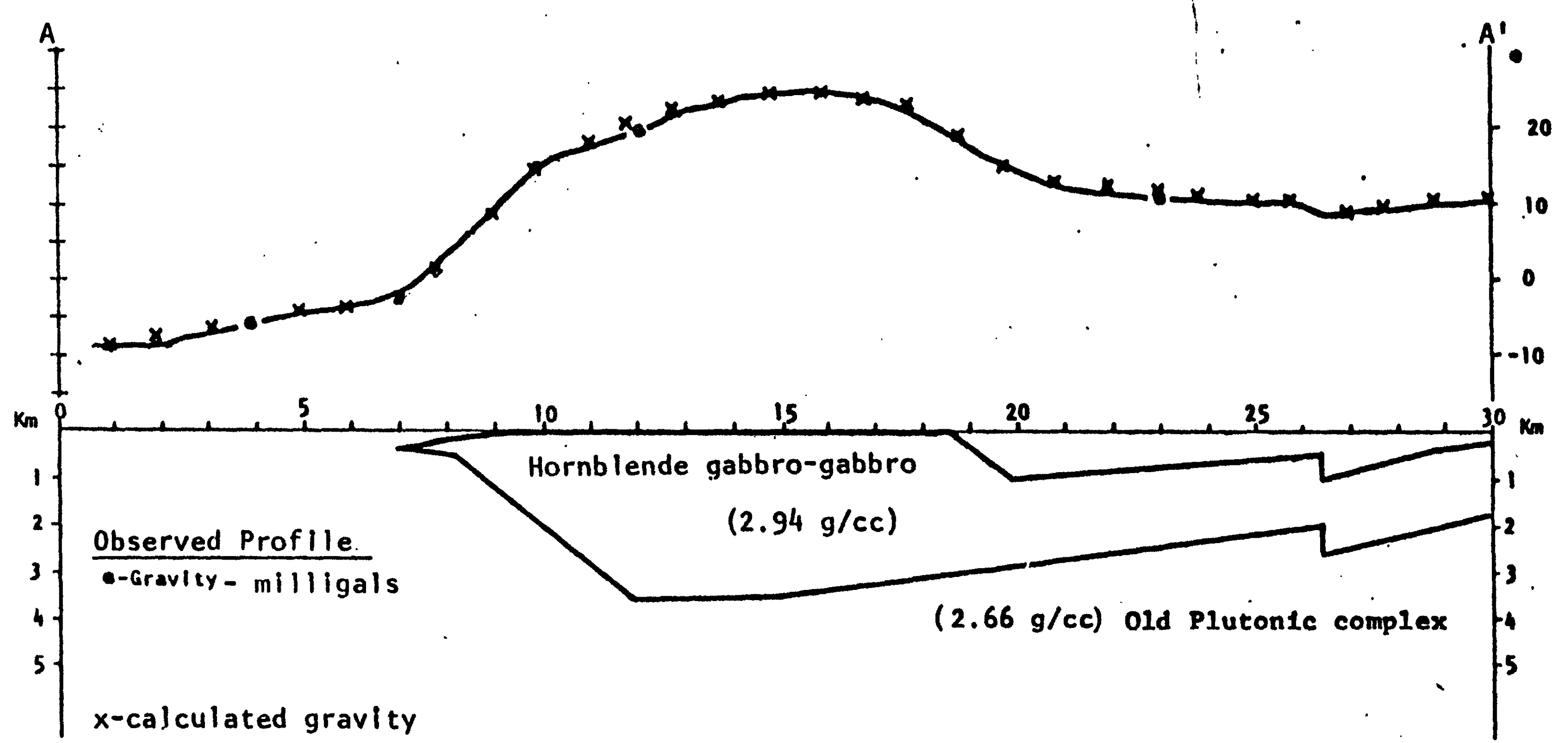
Distribution of gabbro and related rocks

The Mecklenburg-Weddington gabbro complex contains hornblende gabbro (Pzmgbm, Pzmgbo), pyroxene-hornblende gabbronorite, olivine gabbronorite (Pzbm, Pzgbp, Pzgbw) troctolite (Pzgbw) and related smaller bodies of diorite, syenite (Pzsy) monzonite (Pzmz), and mafic metavolcanics (Plate 1). Small contemporaneous granodiorites (Pzgdi) and hornfels occur around the periphery of the gabbros and are related to the emplacement of the gabbro complex. A Landis group granite (Pzgrw) is located east of the Weddington gabbro and may indicate that deeper structural levels are exposed here. Radioactivity and magnetics provide significant information on the distribution and composition of these rocks.

Olivine gabbronorites have the highest magnetic intensities of the Mecklenburg-Weddington gabbros, and troctolites the lowest. Peaks of high magnetic intensity occur over outcrops of known gabbronorite such as at Pineville , Kerr Farms, and areas mapped as gabbro by Hermes (1966). In the Western complex, the area mapped as a gabbro stock by

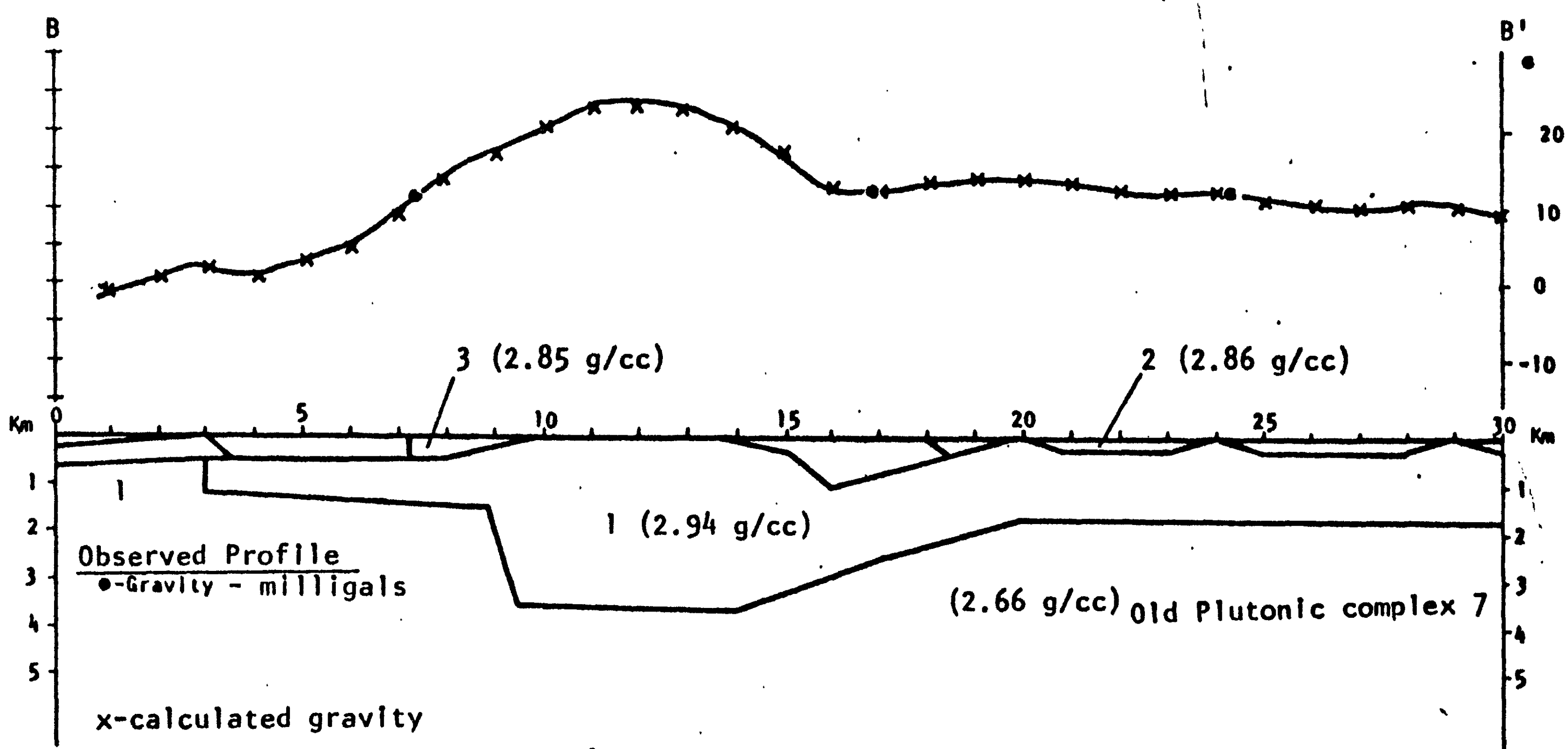
80

Figure 18. Gravity model of the Mecklenburg complex, Profile A, A'. (Plates 1 and 9)


A
A'
20
10
0
-10
Km
0
5
10
15
20
25
30
Km
1
2
3
4
5
Hornblende gabbro-gabbro
(2.94 g/cc)
(2.66 g/cc) Old Plutonic complex
Observed Profile
•-Gravity- milligals
x-calculated gravity

81

Figure 19. Gravity model of the Mecklenburg complex, Profile B, B'. (Plates 1 and 9)



1. Hornblende gabbro-gabbro
2. metavolcanics
3. quartz diorite, etc.

Hermes contains several magnetic peaks (Plate 7 and 8) which indicate that the surface outcrop is not homogeneous, and is more likely a group of coalescing cupolas similar to Pineville and Dinkins Cemetery exposures. A north-south linear low in the magnetic anomaly suggests the influence of both felsic dikes and the shear zone which are observed in hornblende gabbro at the Arrowood quarry.

A small area of the Weddington gabbro was sampled and found to contain rocks of olivine gabbronorite, pyroxene-hornblende gabbronorite, and troctolite composition. A large portion of the Weddington magnetic anomaly has an intensity greater than 6000 gammas. This generally high intensity suggests that this area of the pluton is composed of gabbronorite which has high valves of both Ji and Jr.

The Olde Providence hornblende gabbro has the lowest magnetic intensity of the gabbro bodies. The positive anomaly only reaches 4900 gammas. This unit is adjacent to Olde Providence felsic metavolcanics and Challis Lake mafic metavolcanics of the Concord-Salisbury group. One sample of Olde Providence metavolcanics is a potassium-rich sillimanite-bearing schist, and samples of Challis Lake mafic metavolcanics contain abundant epidote. The mafic volcanics are associated with the lowest magnetic intensity, 4000 gammas. South of the Olde Providence gabbro, a sequence of hornblende gabbro, diorite, and syenite (Pzsy) crops out at increasing elevations in Raintree Estates near Providence Road and Route 51. South of this area, a ledge of coarse-grained monzonite (Pzmz) occurs. The close proximity of these rock types (metavolcanics, diorite, monzonite and syenite) suggests that (1) the Olde Providence body exposes the upper levels of a magma chamber, (2) gabbro has intruded surface pelitic rocks and even its own volcanic pile, (3) differentiation has occurred, and (4) extensive metamorphic and metasomatic alteration has affected the rocks. The low magnetic intensity over this gabbro body may be due to:

(1) Metamorphic alteration of the magnetic mineral in the upper levels of the pluton.

(2) The fact that the more highly magnetic olivine gabbronorite is at a greater depth here than in the other more deeply eroded parts of the complex.

(3) The northern negative magnetic field over the Weddington gabbro interacting with the positive part of the Olde Providence magnetic field.

<u>Radioactivity greater than 600 c/s</u>

High aeroradioactivity anomalies around the periphery of the gabbro plutons appear to be divided into two groups, those with intensities of about 600 c/s and those with greater intensities. The highest anomalies are associated with high grade metamorphosed schist and gneiss; anomalies of about 600 c/s or less are usually associated with granitoid rocks.

The areas of highest intensity are located at Olde Providence (750 c/s) in northeast Weddington quadrangle, and Forest Lake (1000 c/s), in south-central Fort Mill quadrangle. At both locations, gravity gradients, magnetic highs, and soil types indicate mafic igneous rock in contact with radioactive metasedimentary rocks. At Olde Providence, the sharp increase in radioactivity of the metavolcanics at the hornblende gabbro contact, suggests that these rocks are affected by contact and retrograde metamorphism. The only rock sample collected from this area is a well foliated, light-gray muscovite schist composed of undulating folia of muscovite and sericite in a quartz groundmass which contains porphyroblasts of sillimanite and K-feldspar. Most phases are partially altered to sericite which suggests retrograde metamorphism by hydrothermal processes which may have concentrated potassium in a sheared rock. The metamorphic mineral assemblage of sillimanite + K-feldspar = muscovite + quartz indicates that, at a depth of emplacement of 8 km (p. 134), the rock may have reached temperatures of 650°C.

The Forest Lake anomaly is in an area which contains diorite and garnetiferous muscovite schist. The metapelites could have originally contained high concentrations of potassium or could have been affected by metasomatic processes similar to the Olde Providence metavolcanics.

Granitic ring structure

Aeroradioactivity anomalies of less than 600 c/s form a partial ring 13 km in diameter around the western Mecklenburg complex and an arcuate grouping about 9 km in diameter around the northern Weddington gabbro. The only granitic rocks located and mapped within this ring are the Eagle Lake granodiorite (600 c/s) in central Charlotte West quadrangle and the Weddington granite (450 c/s). About 6 other anomalies less than 600 c/s may also represent unexposed granitic plutons related to the gabbro complex.

Summary of Mecklenburg-Weddington gabbro complex

(1) The area of mafic rock outcrop is expressed by close correlation of aeroradioactivity gradients and soils and geologic contacts.

(2) Gravity anomalies, which closely agree with the shape of mafic rock outcrops, indicate 3 interconnected gabbro plutons which may have formed at the intersection of northeast and southeast trending faults or fractures.

(3) The Mecklenburg gabbro plutons have a lopolith-like structure 3.5 to 4.5 km thick which has a sill 1 to 2 km thick extending north.

The sill may connect to exposed gabbro extending south from the Concord gabbro.

(4) Magnetic anomalies and gradients suggest that thin sill-like structures or hornfels may extend south and east of the major gabbro plutons.

(5) Low magnetic intensity suggests that the Olde Providence gabbro may represent upper levels of a pluton which has undergone extensive metamorphic alteration.

(6) The Mecklenburg magnetic anomaly suggests that the gabbro stock is a group of coalescing olivine gabbronorite cupolas which may be cut by north-south non-magnetic dikes and faults.

(7) Aeroradioactivity anomalies indicate possible potassium metasomatism in contact rocks at Olde Providence and Forest Lake.

The Berryhill gravity low

The Berryhill gravity low is a 6-milligal negative anomaly located in the northwest corner of the Charlotte West quadrangle (Plate 9 and 10). The low is associated with an 8 km long northeast trending body of quartz schist and Old Plutonic complex tonalite. The area is well dissected by small streams. Massive quartzite, rich in sulfides, crops out along the railroad cut (CW72) 1 km (0.6 miles) northwest of Berryhill school. Medium-grained tonalite (mgdi), cut by dikes of andesite, crops out at Little Paw Creek and along Olive Church Rd.; quartz schist is commonly found as float in the immediate vicinity; and large areas of felsic metavolcanics have been mapped to the west and east.

The aeroradioactivity (Plate 5, 6) and aeromagnetic (Plate 7, 8) maps of the area show no distinct anomaly that can be related to the gravity low, but small gravity lows commonly indent the western edge of the northern Charlotte belt examples include the -10 isogal configuration in Lake Wylie quadrangle (Plate 9, 10) and the Landis and Churchland plutons further north (Wilson and Daniels, 1980) (figure 15).

The Lake Wylie anomaly is also associated with quartz schist, but the Berryhill area is different in several respects. The Berryhill gravity low has a shorter wavelength, a larger amplitude, and seems to indicate a plug-like body of low density rock similar to the Landis plutons which are characterized by circular gravity anomalies. The Lake Wylie low, however, is broader, of very low amplitude, and appears to indicate the presence of a thin lens of low density rock or a deeper body. Lake Wylie quartz schist also differs from the Berryhill rocks because an aeroradioactivity high and an aeromagnetic high are associated with Lake Wylie quartz schist. No distinct radioactivity or magnetic anomaly is associated with the Berryhill quartz schist suggesting that that body has no surface expression. The density contrast between the average quartz schist (2.66 g/cc) and the tonalite plutonic complex (2.69 g/cc) is approximately 0.03. This would require a 1500 m thickness of quartzite to produce the observed negative anomalies.

The shape of the Berryhill anomaly seems to be influenced by a body of higher density mafic rock to the north, which trends east-west. If the body causing the anomaly is quartzite or quartz schist, it must dip to the south, because the center of the gravity anomaly is located south of the surface outcrops of these rocks. The quartzite would have to be a roof pendent of Old Plutonic rock, or, a down-faulted section of the complex associated with the linear anomalies extending from Berryhill to Hickory Grove. On the other hand, the location of the gravity low in the western Charlotte belt, its circular shape and its association with felsic volcanics suggest a subsurface granite pluton of the Landis group (Wilson and Daniels, 1980).

The Mill Creek metagabbro

The Mill Creek metagabbro crops out at the head waters of Mill Creek, in southwest Belmont quadrangle at the North Carolina-South Carolina state line (Plate 1). Metadiorite, diorite, mafic metavolcanic, plutonic complex granodiorite, and quartz schist also crop out in the surrounding area.

The low amplitude geophysical anomalies associated with the metagabbro suggest it is a thin tabular body of rock. An elongated magnetic anomaly of approximately 400 gammas, marked by the closure of the 4500 gamma isogam, helps outline the metagabbro (Plate 7). This anomaly may be the product of the Ji and Jr of the metavolcanics and hypabyssal intrusive, which have Q values greater than 0.50, because the measured magnetic susceptibility of one metagabbro sample is 0.09×10^{-3} c.g.s., that compared with the Old plutonic complex average, 1.2×10^{-3} c.g.s. Locally, however, the magnetic susceptibility of the plutonic basement rock may be lower. The metagabbro coincides with the west leg of a "U"-shaped aeroradioactivity anomaly that is enclosed by the 200 c/s isopleth (Plate 6). The aeroradioactivity anomaly is much larger and extends further north than the magnetic anomaly. This may indicate that the less magnetic metagabbro could be more extensive than the mapped outcrop area.

The Mill Creek metagabbro, therefore, is probably a thin tabular body of rock and may not be directly associated with the other large mafic plutons in the area. Its association with quartz schist may mean that it was emplaced at a high level in the Old Plutonic complex.

In the western part of the map, mafic metavolcanic rocks of the Old Plutonic complex occur with quartz schist and felsic metavolcanics (mv). Some of the rock types, such as sericite schist (LW1150) associated with the metavolcanic and metasedimentary rocks, bear a strong resemblance to the mudstone, phyllite, and metavolcanic rocks in the Slate belt. This similarity has encouraged many authors (Kerr, 1875, Overstreet and Bell, 1965a) to correlate metasedimentary and volcanic rocks on either side of the Charlotte belt.

The Gold Hill-Silver Hill fault system

The Gold Hill fault has been considered the western side of a shear zone that separates the Charlotte belt from the Slate belt. Magnetic and gravity gradients coincide with the trace of the fault along the western edge of the phyllite unit in Midland quadrangle, but further south, geologic evidence is not conclusive. If the fault exists in this area, it may follow the gravity gradient west of the Stallings granodiorite which bifurcates in the Weddington quadrangle. A minor splay may pass between the Olde Providence and Weddington gabbro along the south Mecklenburg fault zone and the major fault may form the contact between the Weddington gabbro and granites. These gravity and magnetic gradients can also be explained as subsurface sill-like parts of the Mecklenburg gabbro lopolith. Based on the computer model (fig. 20), the slate belt may consist of a wedge of higher density rocks (2.76 g/cc) overlying lower density (2.66 g/cc) plutonic basement rocks similar to those exposed in the adjacent Charlotte belt.

The geophysical signature of the Silver Hill fault is subtle. The gravity gradient (Plate 9, 10) over the fault is not prominent because the density contrast between the metasedimentary rock and Old Plutonic basement is only 0.1. According to the gravity model the major juxtaposition of densities probably occurs at a depth of 1.2 km. A slight magnetic gradient (Plate 7, 8) between the 4240 and 4260 isogams occurs over the fault, and a line of elongated anomalies with 4240 isogam closures occur east of the fault. The gradient and the negative anomalies could denote the offset of magnetic rock units. The flat side of the 250 c/s contour (Plate 5, 6) in southwestern Bakers quadrangle may reflect the southwestern extension of the trace of the fault.

Computer model

The computer model of section CC′, (Plate 9, 10, 1, 2,), across the Silver Hill fault and Charlotte belt, is matched to the residual gravity profile of CC′, (fig. 20); and is based on the densities of collected rock samples (Appendix D). The Stallings granodiorite was given a density of 2.63 g/cc, the average of 3 samples of the rock. The phyllite, mudstone, and metavolcanics were modeled as one unit and density for the unit (2.76 g/cc) was derived from 30% metavolcanics at 2.86 g/cc; 30% phyllite at 2.70 g/cc; and 40% Cid mudstone at 2.74 g/cc.

The model suggests a westward tapering unit of metasedimentary rock which overlies Old Plutonic complex basement. The basement generally rises to the west but has an abrupt 0.8 km vertical offset at 27 km. Geologic, magnetic and radioactivity evidence strongly suggests it is the Silver Hill fault. An extension of the fault, south of this point, causes its trace to pass just north of the Bakers quarry in southeast Matthews quadrangle where disrupted horizontal beds of Cid mudstone in the quarry may be an expression of the fault. The fault also offsets a mafic intrusive unit which has an antiformal pattern in southeastern Matthews quadrangle (Plate 1) suggesting strike-slip motion along the fault.

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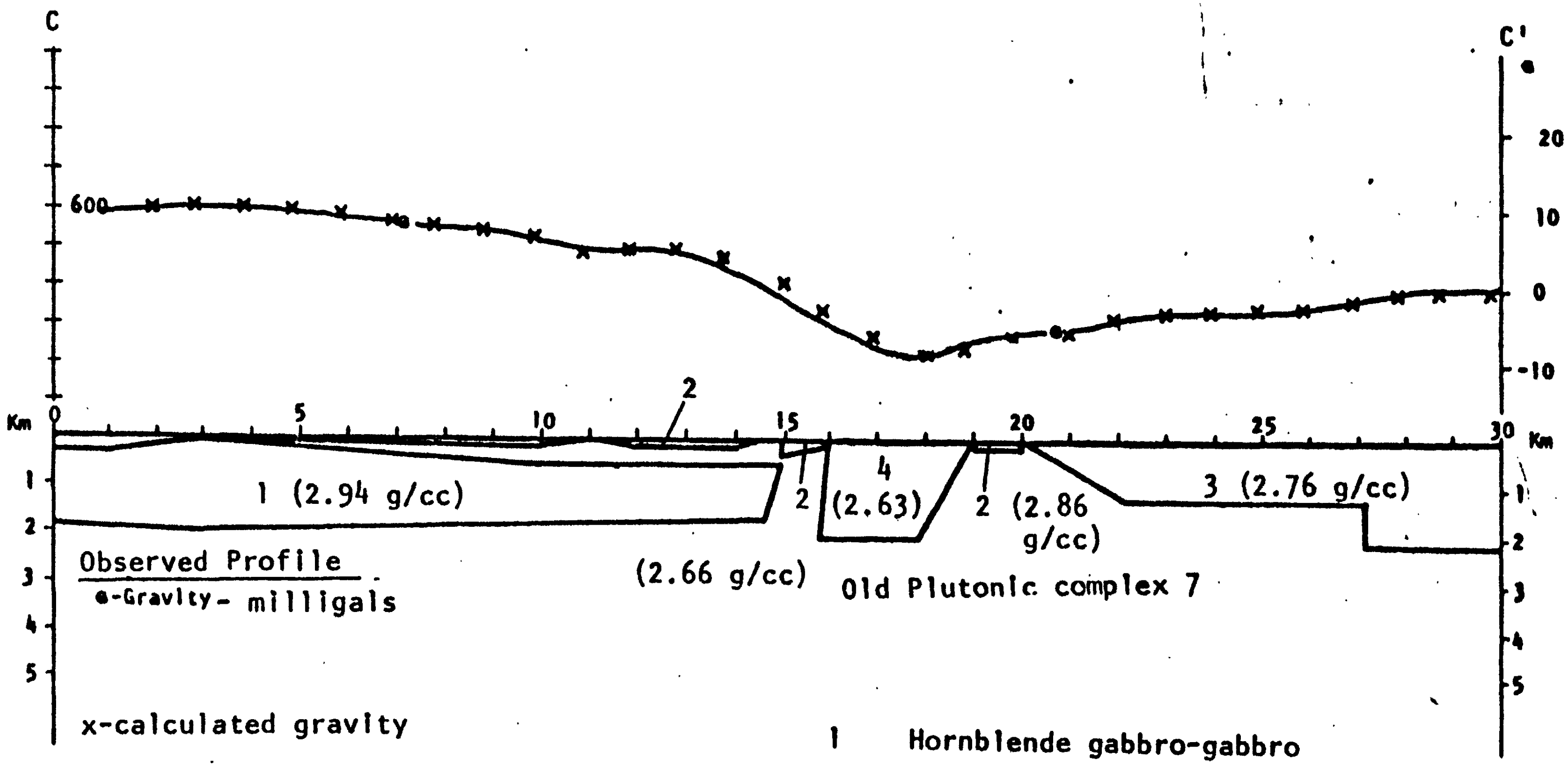
Figure 20. Gravity model of Profile C, C', Charlotte belt-Carolina slate belt boundary and Stallings granodiorite. (Plates 1 and 9)



1 Hornblende gabbro-gabbro
2 metavolcanics
3 Carolina slate belt meta-igneous and metasedimentary rocks
4 Stallings granodiorite

Concord-Salisbury supergroup , 1,4
Old Plutonic complex - 7, 2.

The Stallings Granodiorite

The Stallings granodiorite is located in northwestern Matthews quadrangle near Stallings, North Carolina (Plate 1,2). It is a medium-grained metamorphosed granodiorite body about 3 km (1.5 miles) in diameter. The surrounding rocks are metavolcanics which include mafic volcanics, rhyolite, and dacite flows and tuffs.

The geophysical anomalies over the granodiorite are small but distinct. The aeroradioactivity anomaly (Plate 5, 6) enclosed by the 150 c/s contour has a northward trend which seems to reflect the distribution of metavolcanic rocks rather than granodiorite. Magnetic and gravity anomalies associated with the pluton have strong northeast trends and may more accurately describe the pluton's subsurface size and shape. A very low amplitude magnetic anomaly (50 gammas) cuts across the southwestern end of the mapped granodiorite, and coincides with a high in the low gravity field of the area. These anomalies suggest a roof pendent of metavolcanic rock; or alternatively, the location of an Early Mesozoic diabase dike (MA876C) that is exposed about 6 km south of the Mecklenburg - Union County line along the 4400 gamma contour. The continuous occurrence of granite-derived soil and the low amplitude of the anomalies indicate that this cross-cutting structure is a minor feature.

The model of the Stallings granodiorite, was matched to the residual of gravity profile C, C′ (Plate 9,10). The density used for the granodiorite was 2.63 g/cc resulting in a 0.03 g/cc density contrast with Old Plutonic complex granodiorite. These parameters require a 2 km (1 mile) thick pluton, with steep west-dipping sides, that intrudes Old Plutonic complex (mgdi) granodiorite, and a thin layer of metavolcanic rock (density contrast 0.20).

Mafic volcanics followed by felsic volcanics suggest a silicic volcanic center which developed in a terrestrial environment. The Stallings granodiorite could have intruded the metavolcanics but also could have contributed extrusive products to the felsic volcanic ash and tuff deposits nearby. Silicic volcanic flows usually do not travel far from their vents, and the fact that metadacitic lava containing flow structures (MA856) occurs close to exposures of Stallings granodiorite (MA855) is evidence that the lava may be related to the plutonic rock.

REGIONAL STRUCTURE AND TECTONIC MODELS

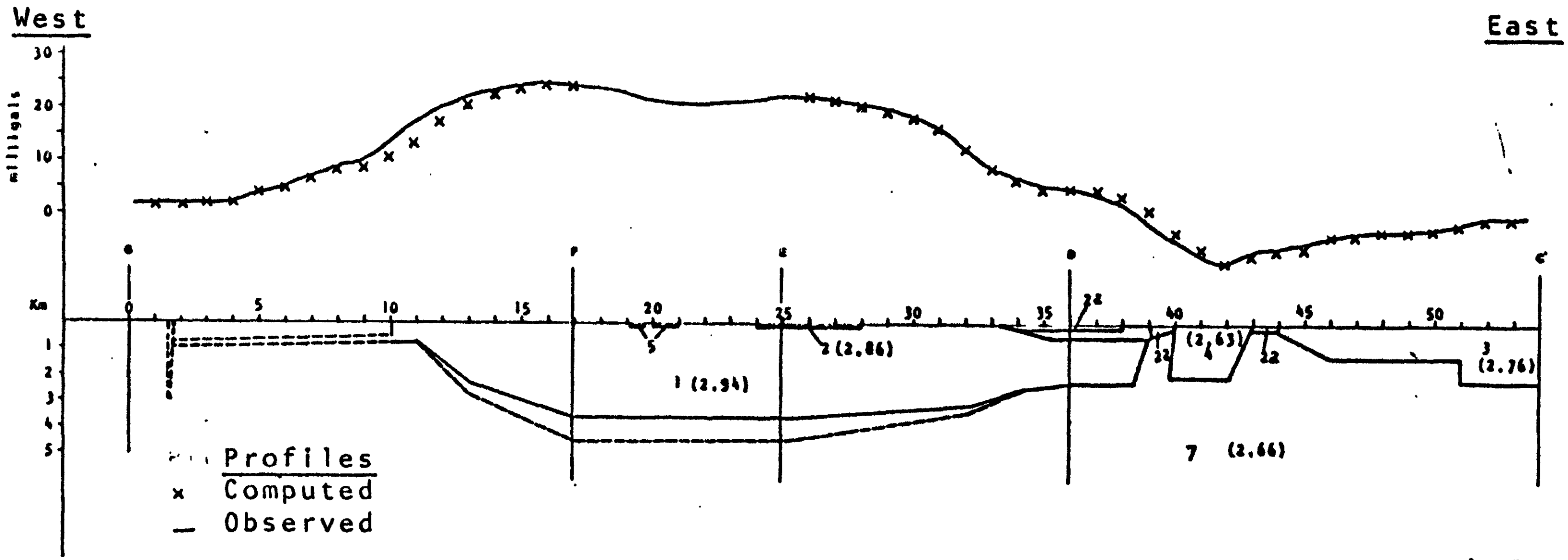
Regional Structure

The gross structure of the Charlotte and Slate belts in the study area may be antiformal - synformal, respectively as suggested by the east-west gravity model (fig. 21). The Charlotte belt is interpreted as a tilted composite batholith which has been eroded, exposing higher level granodiorite, metavolcanic, and metasedimentary rocks in the east, and lower level plutonic tonalite and quartz diorite in the west. This pattern is repeated along the length of the belt. North of the study area, in the northern Charlotte belt, small gabbros and Salisbury type granodiorites occur in the east; the largest gabbro complexes in the eastern and central section; and coarse-grained post metamorphic Landis granites in the west (Wilson and Daniels, 1980) (fig. 21). The batholith is divided along its length into segments containing different plutonic assemblages and different gravity and magnetic anomaly patterns. The differences in the segments may be the result of the level of erosion of the batholith or of the structural setting in which the plutons were emplaced.

The thin lenses of quartz schist and mafic volcanics in the Old Plutonic complex rocks of the western study area and along the western edge of the Charlotte belt, suggest that the Charlotte belt was transgressed by a western sea. This would support Williams' (1978) correlation of the Charlotte and Carolina slate belts with the Avalon terrain of eastern Newfoundland.

Figure 21. West-east structure section C', D, E, F, G. (Plate 1 and 9)

1. Hornblende gabbro-gabbro
2. Metavolcanics
3. Carolina slate belt metaigneous and metasedimentary rocks.
4. Granodiorite
5. Granodiorite



( ) Density, g/cc

Concord-Salisbury supergroup, 1,2,4,5

Old Plutonic supergroup, 7,2a

Tectonic models of the Piedmont

The most successful plate tectonic model of the Appalachian orogen has been constructed from the geologic section through Newfoundland by Bird and Dewey (1970) and Williams (1978). This section between Grenville basement and the Avalon platform includes obducted ophiolites, the remains of a proto-Atlantic ocean, a block of continental crust and an island arc. Attempts to extend this model to the southern Appalachians have resulted in a plethora of models seeking the suture between the North American and African plates. Broad gravity gradients which may represent features in the crust have been proposed as the location of these sutures.

The Appalachian regional gravity gradient

Griscom (1963) first called attention to the west-dipping gravity gradient that extends the full length of the Appalachians from Gaspe Peninsula to Alabama (Fig. 14A). He interpreted it as a major break in the crust, and further proposed that the gradient indicated a 6.5 km uplift on the southeastern side which may have initiated gravity sliding to the west producing thrusts and folds of the Appalachian belts.

Rankin (1975, p. 327) suggested an allochthonous structure for the Inner Piedmont and recognized that exposures of billion year-old granitic gneisses in the Pine Mountain and Sauratown Mountains area correlated with the steep part of the regional gavity gradient which lies between the Kings Mountain and the Charlotte belts. He further concluded that the gneiss and gradient indicate the edge of the North American continental plate.

Haworth (1978), using gravity, magnetic and seismic data, also correlated the positive east edge of the gravity gradient in Canada with the eastern edge of the Grenville basement.

Long (1979, p. 180) interpreted this gradient in the Piedmont of Georgia and South Carolina as a rifted continental margin and the adjacent Carolina slate belt as a rift zone 160 km wide that contains microcontinental blocks. The rift zone is indicated by a 5 km thick high-velocity layer over a low-velocity crustal layer.

South of the study area the Charlotte belt abruptly widens, the regional Appalachian gravity gradient flattens (figs. 1, 14(B), and 15), gravity anomalies over gabbros are much lower in amplitude, and post metamorphic granitic and Old Plutonic complex plutons occur side by side (Fullagar, 1980). At the 35° parallel, (figs. 14(B) and 15) the 0 isogal is deflected east around the southern end of the Mecklenburg-Weddington gabbro complex, and the -10 isogal is deflected west following the trend of the Kings Mountain belt. The deflection of the 0 and -10 isogals and the relatively small wavelength of the anomalies over the gabbro complexes and Kings Mountain belt indicate that (1) the wide part of the Kings Mountain belt and the Mecklenburg-Weddington and Concord gabbro complexes are relatively shallow features; and (2) Charlotte belt rocks may underlie Kings Mountain as well as the Carolina slate belts. This implies that the fault which forms part of the Kings Mountain Charlotte belt boundary (Horton, 1980) and the accompanying gravity gradient (figs. 14(B) and 15) may not represent a plate suture (Zietz and Hatcher, 1980), a rifted continental margin (Long, 1979), or the edge of the Grenville basement (Rankin, 1975).

Interpretations of seismic data

Published reports on seismic traverses by Cook and others (1979), and Harris and Bayer (1979) have called for a new interpretation of the Appalachian orogen. The COCORP seismic traverse through Tennessee, North Carolina, and Georgia shows horizontal reflections at 3 to 5 seconds through most of the traverse, and east-dipping reflections near the Brevard fault zone and at the western edge of the Charlotte belt. The east side of the Charlotte belt contains west-dipping reflections above and below the horizontal reflector to 5 seconds. The seismic data were interpreted as indicating that allochthonous crystalline Piedmont rocks overlie miogeosynclinal sedimentary rocks that extend from the Valley and Ridge to the western edge of the Charlotte belt. A plate tectonic model similar to the Newfoundland model of Bird and Dewey (1970) is also described, but, because no ophiolites are found in the area, plate boundaries are considered to be cryptic sutures.

Harris and Bayer (1979) using seismic data from various parts of the Appalachians extend the east-dipping decollement of Cook and others (1979) from the Appalachian plateau to the continental shelf in both the northern and southern Appalachians. They advocate interpreting the seismic reflections utilizing the concepts of thin-skinned tectonics found in the thrust-faulted western part of the orogen. The seismic reflections under the Charlotte belt could be interpreted by these criteria, as a structure similar to the toe of an overthrust, and the Silver Hill fault as an underthrust fault. The limited thickness of the modeled plutons (3.5 to 4.5 km) would support this type of interpretation by suggesting that they were truncated by splays of the decollement described by Harris and Bayer (1979).

EMPLACEMENT HISTORY OF THE NORTHERN CHARLOTTE BELT PLUTONS

Introduction

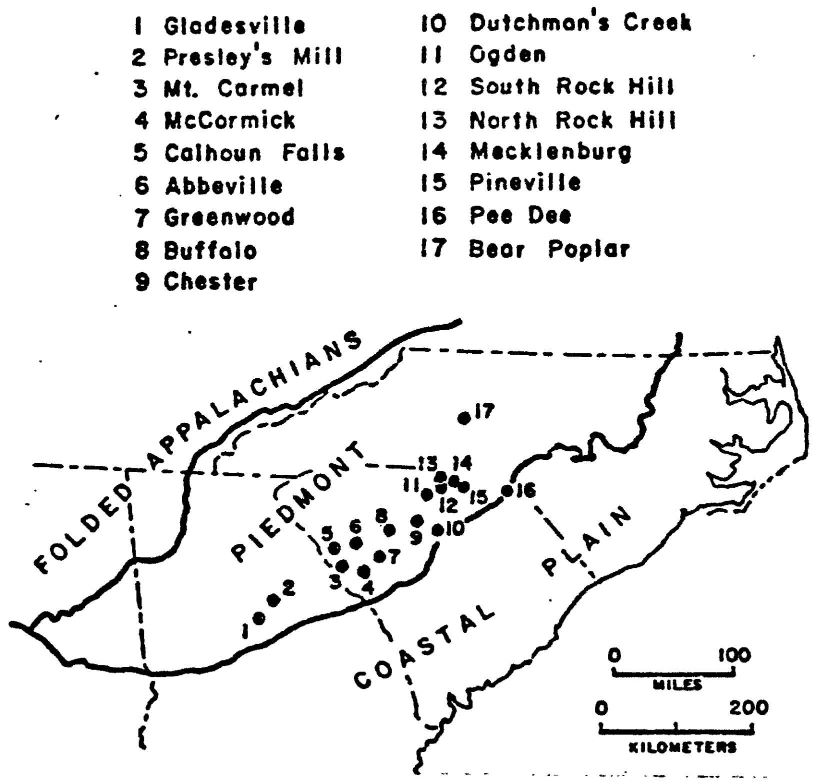
The sequence of emplacement of plutons in the northern Charlotte belt is discussed so as to show the wide distribution of the plutons (fig. 22) and explain their arrangement into stratigraphic groups forming a composite batholith. Comparisons of gabbro complexes establish the similarity of composition, texture, fabric, and related differentiates in the wide spread and easily traced gabbros of the Concord-Salisbury supergroup. Volcanic ring structures help determine the depth of emplacement of gabbro and of the related Salisbury type granodiorite. The ages of the different plutons fall into groups corresponding with the relative levels of emplacement of plutons in the study area, suggesting a layered plutonic sequence for the composite batholith.

Units of the Charlotte belt composite batholith

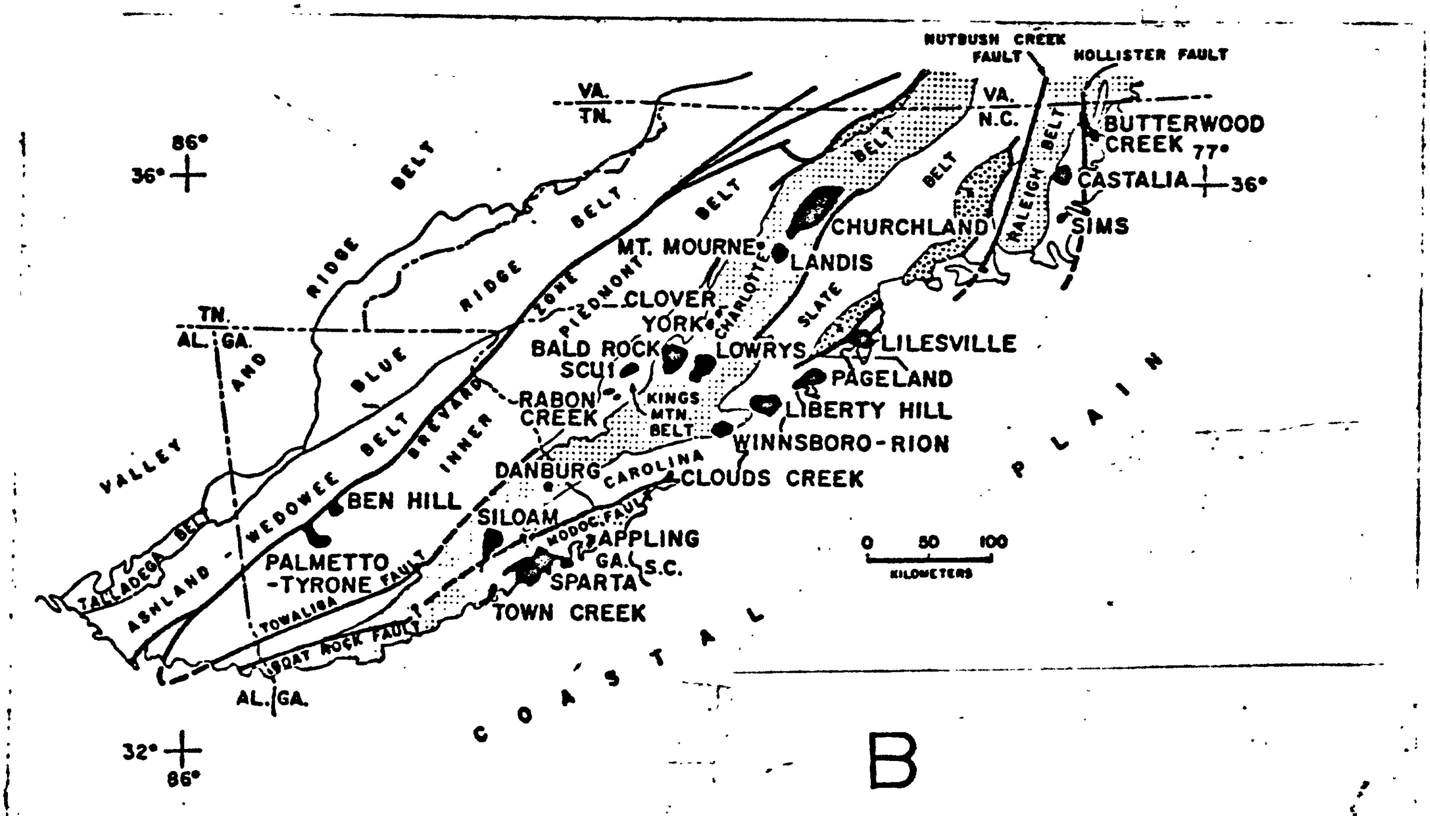
The Old Plutonic supergroup is composed of largely 545-490 m.y. medium grained quartz diorite, tonalite, and granodiorite plutons. In the study area and the northern Charlotte belt, these plutons have no well defined shape or associated magnetic or gravity anomalies. This may be attributed to the close proximity of denser gabbros of the Concord-Salisbury group and the lower density granites of the Landis group.

The Concord-Salislbury supergroup contains two genetically different groups of plutons, Salisbury type granodiorites and differentiated gabbros and associated diorite and syenite. The

Figure 22. Location of post-metamoprhic plutons in the southern Appalachian Piedmont, gabbro (A), granite (B) (Speer and others, 1979, p. 137 and 140).


1 Gladesville
2 Presley's Mill
3 Mt. Carmel
4 McCormick
5 Calhoun Falls
6 Abbeville
7 Greenwood
8 Buffalo
9 Chester
10 Dutchman's Creek
11 Ogden
12 South Rock Hill
13 North Rock Hill
14 Mecklenburg
15 Pineville
16 Pee Dee
17 Bear Poplar
FOLDED APPALACHIANS
PIEDMONT
COASTAL PLAIN
0 100
MILES
0 200
KILOMETERS

A


NUTBUSH CREEK FAULT
HOLLISTER FAULT
VA.
TN.
VA.
N.C.
86°
36°
77°
36°
BUTTERWOOD CREEK
CASTALIA
SIMS
CHURCHLAND
LANDIS
MT. MOURNE
RALEIGH BELT
BELT
CHARLOTTE
SLATE
VALLEY AND RIDGE BELT
BLUE RIDGE BELT
PIEDMONT ZONE
INNER
BREVARD
TN.
AL. GA.
CLOVER
YORK
BALD ROCK
SCU1
LOWRYS
LILESVILLE
PAGELAND
LIBERTY HILL
WINNSBORO-RION
KINGS MTN. BELT
RABON CREEK
DANBURG
CAROLINA
CLOUDS CREEK
BEN HILL
WEDOWEE BELT
ASHLAND
TALLADEGA BELT
PALMETTO -TYRONE FAULT
TOWALIGA
GOAT ROCK FAULT
SILOAM
MODOC FAULT
APPLING GA.
S.C.
SPARTA
TOWN CREEK
AL. GA.
32°
86°
COASTAL PLAIN
0 50 100
KILOMETERS

B

Salisbury type granodiorites are usually small and have small amplitude negative gravity and magnetic anomalies associated with them. The gabbros range from small intrusions to large complexes with high amplitude positive gravity and magnetic anomalies. The granodiorites range in age from 413 to 362 m.y. and the gabbros are dated at 425±110 m.y.

The Landis supergroup is made up of coarse porphyritic "big feldspar" granites, usually associated with rounded well-defined negative gravity and magnetic anomalies. These plutons are dated at 325-265 m.y.

Gabbro complexes of the Concord-Salisbury supergroup

In this section the Mecklenburg-Weddington gabbro complex will be related to other gabbro complexes in the Charlotte belt. These gabbros have common chemistry, textures, rock type, and ages and form an extensive unit that extends from Virginia to Georgia. These gabbros are probably the most important unit in the batholith because they can be easily identified and traced, even below the surface, by their positive gravity and magnetic anomalies and their distinctive soils. This supergroup can also be used to identify structural levels in the batholith because of its intermediate position in the structure.

Mecklenburg-Weddington complex

The Mecklenburg-Weddington gabbro complex contains mafic metavolcanics, syenite, dacite, hornblende gabbro, olivine gabbronorite and troctolite, and may contain even more mafic rocks at depth. Cupolas of olivine gabbronorite, and roof pendents of hornblende gabbro indicate that the hornblende gabbro was probably the upper level of a differentiated magma chamber. Hermes (1966, p. 37; 1968, p. 293) documents the argument that the hornblende gabbro is the product of hydration and is associated with incorporation of silicic rocks rather than regional dynamothermal metamorphism. Unlike the Mt. Carmel and the Concord systems, the Mecklenburg system appears to have had two magma chambers. The upper levels of the complex are exposed over what was the eastern magma chamber which include the Challis Lake mafic metavolcanics, and the Olde Providence hornblende gabbro. The hornblende gabbro and diorite appears to intrude felsic metavolcanics. Associated with the diorite is medium-grained hornblende syenite and monzonite at Providence Church. Lower levels of the system are exposed in the west, over what was the western magma chamber at the Mecklenburg and Pineville gabbro, and south over the Weddington gabbro.

The western magma chamber also displays a 13 km ring of high radioactivity which is the same diameter as the syenite ring structure of the Concord gabbro complex. The Mecklenburg ring is attributed to small contemporaneous high-potassium granodiorites instead of syenite. The Mecklenburg complex is associated with a smaller gravity anomaly (24 milligals) than the Concord (32 milligals), suggesting that the Mecklenburg has less mass and, therefore, (1) was a smaller system that did not differentiate large amounts of syenite or (2) was the same size, did differentiate syenite and formed a ring structure which was subsequently removed by erosion producing the present difference in mass of the two complexes.

Although mafic volcanic systems such as these do not usually form calderas as do more silicic systems, the ring structures found in these gabbros must be directly related to the size of the magma chambers and, therefore, can be used to estimate the depth of emplacement of the pluton.

Concord complex

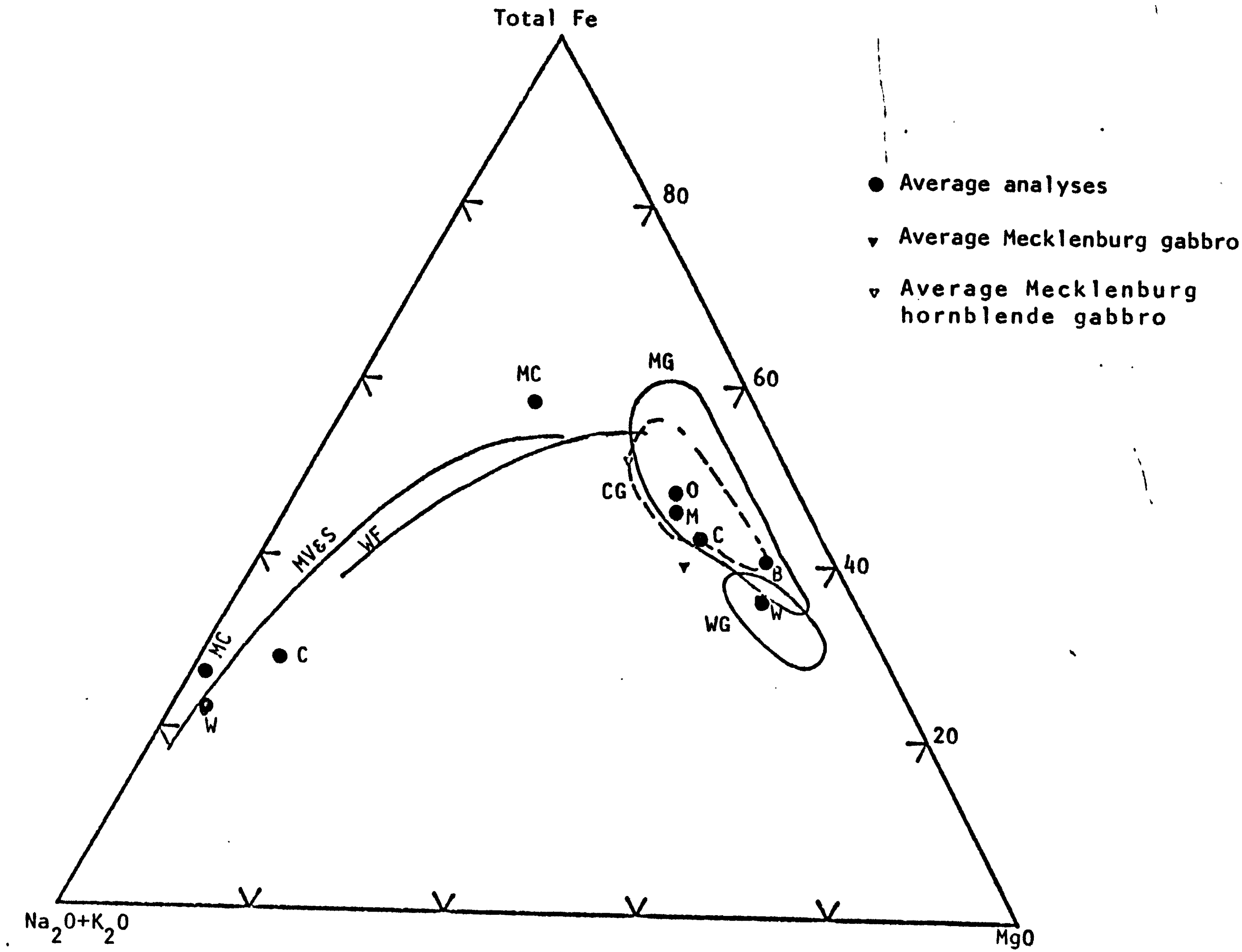
The Concord gabbro complex is located in Cabarrus County, North Carolina, 75 km north of the Mecklenburg complex. It is made up of a 10 km (6 miles) discontinuous circle of augite syenite and a core of hypersthene-bearing hornblende gabbro (Bates and Bell, 1965) that have mineral textures almost identical with those of the Mt. Carmel gabbro (Medlin, 1968, p. 197). The pluton is emplaced in massive and foliated diorite and mafic rocks. The average chemical composition plots closer to the MgO apices of the MgO - total iron - total alkali diagram (fig. 23) than the Mt. Carmel complex, suggesting that deeper levels of the complex are exposed.

Interpretation of the gravity by Morgan and Mann (1964) shows the syenite as shallow bodies. Further interpretations of magnetic data by Bates (Bates and Bell, 1965) show an increase in magnetic intensity attributed to possible concentration of magnetite along the contacts of the gabbro and syenite (Bates and Bell, 1965, p. 1). A true syenite ring dike around a stoped block of gabbro would have produced distinct low gravity and magnetic anomalies.

Mt. Carmel Complex

The Mt. Carmel complex is located in McCormick County, South Carolina, near the Georgia border. The complex is about 6 km (4 miles) in diameter, and intrudes slate belt rocks which are metamorphosed to the pyroxene hornfels facies. The gabbro is layered and shows complete gradations to metagabbro (Medlin, 1968, p. 186). Metamorphism was probably by deuteric reactions, associated diorite and syenite displaying "cataclastic effects." Medlin concludes that the diorite and the syenite are the differentiated products of the gabbro. The average chemical compositions of the Mt.Carmel rocks plot as the most highly

Figure 23. MgO - Total iron (as Fe_2O_3) - total alkalies (weight percent) diagram of rock analyses from some Piedmont gabbroic complexes. Data for the Buffalo (B), Concord (C), Mecklenburg (M), Ogden (O), Weddington (W), Mt. Carmel (MC) gabbroic and syenite rocks: Butler and Ragland (1969, p. 170); and average analyses of Mecklenburg rocks: Hermes (1968, p. 280-281). Fields: MG Mecklenburg gabbro, CG Concord Gabbro (Butler and Ragland, 1969, p. 184) and WG Weddington gabbro. Trends: MV&S metavolcanic and Salisburg, WF West Farmington, Butler and Ragland (1969, p. 172).


Total Fe
80
60
40
20
MC
MG
CG
O
M
C
B
W
WG
MV&S
WF
MC
C
W
Na_2O+K_2O
MgO
Average analyses
Average Mecklenburg gabbro
Average Mecklenburg hornblende gabbro

differentiated on the MgO - total iron - total alkali diagram (fig. 23).

Medlin establishes the depth of emplacement at 6-16 km (4-10 miles) (Medlin, 1968, p. 176). This is the depth of a high level magma chamber. The locaton of the complex in slate belt rocks suggests that a Charlotte belt composite batholith underlies the slate belt in this area.

Chemical Analysis of Plutons

The chemical composition of 17 samples of intrusive rocks from the area are listed in Table 4 and plotted on CaO-K_2O-NA_2O (fig. 24) and MgO-Total Fe-Total alkali diagrams (fig. 25). Most of the samples are from mafic intrusives and small metagabbro plutons in the Charlotte belt. Sample WKF5 is a troctolite and W1003 is a gabbronorite. Both samples are from the Weddington gabbro. Most of the samples plot within the fields of the Concord and Mecklenburg gabbros (fig. 23) although some follow the West Farrington trend of differentiation (Butler and Ragland, 1969, p. 184). The West Farrington trend represents differentiation in a zoned 500 m.y. pluton "with swarms of xenoliths" located in the slate belt 40 km from Raleigh, N.C. (Butler and Ragland, 1969, p. 173). The few samples that follow that trend may suggest some 500 m.y. mafic bodies exist in the Old Plutonic group but all of these samples are near contacts with felsic plutonic rocks or show signs of severe disequilibrium. The increase in K_2O and Na_2O in these rocks is more likely caused by contamination than by differentiation. Samples WKF5 and W1003 have less total Fe than the Mecklenburg and Concord fields. This indicates that they are less differentiated and confirms the modal trends that suggest the Weddington gabbro represents an earlier or lower level magma differentiated from the Mecklenburg magma chamber.

A comparison of the average compositions of Mt. Carmel, Ogden, Buffalo, Concord, Mecklenburg (data from Butler and Ragland, 1969, p. 170, 171) and Weddington (fig. 23) shows a differentiation trend extending from the Weddington - the most mafic - to Mt. Carmel - the most differentiated. The Concord, Mt. Carmel, and Mecklenburg have syenites associated with them, and the syenites complete the differentiation trend. The total composition of the plutons and the differentiates associated them are probably due to the level of erosion of the magma chamber.

Cumulus textures of plagioclase have been reported in the South Rock Hill gabbro pluton, South Carolina; olivine cumulus textures in the Barber gabbro pluton, North Carolina (Butler and Ragland, 1969, p. 178); and cumulus plagioclase in the Weddington gabbro. Other cumulus textures and more mafic assemblages may occur at deeper levels of the magma chamber if the Mecklenburg and other gabbros of the Charlotte belt have not been truncated by tectonic transport from the east (Harris and Bayer, 1979).

Charlotte belt volcanic province

Old plutonic group plutons in the northern Charlotte belt are flanked and partly covered by a thin veneer of predominantly felsic volcanic rock that appears to be genetically related to the plutons. In the slate belt, earlier Salisbury type plutons have been chemically related to slate belt volcanic rocks (Butler and Ragland, 1969, p. 180). The Olde Providence gabbro and the Stallings granodiorite are also associated with extrusive rocks. The ring structures of the Concord, Mecklenburg, and Mt. Carmel gabbroic complexes, their associated syenite differentiates, and the predominance of felsic metavolcanic deposits identify the Charlotte belt as the site of a large

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Table 4. Chemical analysis of some igneous rocks from southern Mecklenburg Co. and vicinity.

Table 4. - Chemical analysis of some igneous rocks from southern Mecklenburg Co, and vicinity

Field No.		CW1129A	WKF5	W1003	BE1178	CE4627B1	CW70A	W206	MH891	W213
SIO2	%	48.0	44.4	47.0	46.5	48.1	43.8	49.3	49.0	47.4
AL203	%	16.7	17.1	19.3	20.4	15.5	16.9	18.4	13.7	17.9
FE203	%	4.7	1.3	1.6	3.5	4.2	3.2	2.9	3.6	4.8
FEO	%	6.1	6.2	5.5	5.1	7.6	6.6	4.0	5.2	6.5
MGO	%	6.8	17.1	10.4	6.4	7.7	12.0	7.3	10.2	4.5
CAO	%	8.3	8.2	11.0	13.1	10.5	9.2	10.4	11.8	8.7
NA20	%	3.3	1.9	2.2	1.4	2.0	1.4	2.7	1.6	4.0
K20	%	1.7	0.37	0.14	0.17	0.25	0.31	0.60	0.41	1.4
H20+	%	0.81	1.8	0.71	1.9	1.5	4.4	1.7	2.1	0.92
H20	%	0.15	0.28	0.19	0.14	0.10	0.15	0.23	0.13	0.13
TIO2	%	1.7	0.13	0.38	0.40	0.89	0.34	0.71	0.44	1.7
P205	%	0.34	0.08	0.09	0.06	0.13	0.13	0.23	0.15	0.72
MNO	%	0.20	0.11	0.13	0.15	0.20	0.18	0.12	0.18	0.19
CO2	%	0.03	0.59	0.24	0.03	0.19	0.04	0.04	0.05	0.15
ROC-SUM		99.	100.	99.	99.	99.	99.	99.	99.	99.

Field No.		WH763	W466C	W466A	CW1024B	CW1111B	QFM1063D	MH767	QFM3
SIO2	%	61.6	63.4	63.2	55.3	53.3	46.8	53.0	73.7
AL203	%	15.4	16.7	17.3	15.3	16.6	13.7	17.1	12.9
FE203	%	2.8	1.4	2.1	4.6	3.6	3.1	3.6	0.75
FEO	%	3.4	2.0	1.2	4.4	6.5	6.4	4.9	0.52
MGO	%	2.7	0.61	0.52	3.2	4.1	11.2	4.4	0.17
CAO	%	6.1	1.4	1.1	6.6	8.5	10.7	9.9	1.3
NA20	%	3.5	5.2	5.8	4.1	3.0	1.5	2.5	3.4
K20	%	1.3	6.8	6.8	1.6	0.62	0.22	0.50	4.8
H20	%	0.79	0.22	0.21	0.64	1.0	2.8	2.1	0.44
H20	%	0.12	0.10	0.11	0.13	0.18	1.6	0.11	0.11
TIO2	%	0.54	0.79	0.61	1.9	0.87	0.47	0.56	0.13
P205	%	0.21	0.12	0.09	0.69	0.22	0.09	0.17	0.05
MNO	%	0.11	0.12	0.12	0.17	0.20	0.15	0.14	0.03
CO2	%	0.04	0.03	0.02	0.17	0.03	0.42	0.02	0.39
ROC-SUM		99.	99.	99.	99.	99.	99.	99.	99.

Chilled contact gabbro = CW1129A; troctolite=WKF5; Olivine gabbrononite=W1003; metagabbro=BE1178, CE462B1, CW70A, W206; diorite=MH891, W213A; tonalite=MH763; monzonite=W466C; syenite=W466A; amphibolite and mafic dikes=CW1024B, CW1111B, QFM1063D, MH767; and felsic dikes=QFM3.

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Figure 24. CaO-K_2O-Na_2O diagram of chemical analyses of some rocks from southern Mecklenburg Co. and vicinity. Meta-volcanic and Salisbury trend (MV&S), West Farrington trend (WF) from Butler and Ragland (1969, p. 172) (weight percent).

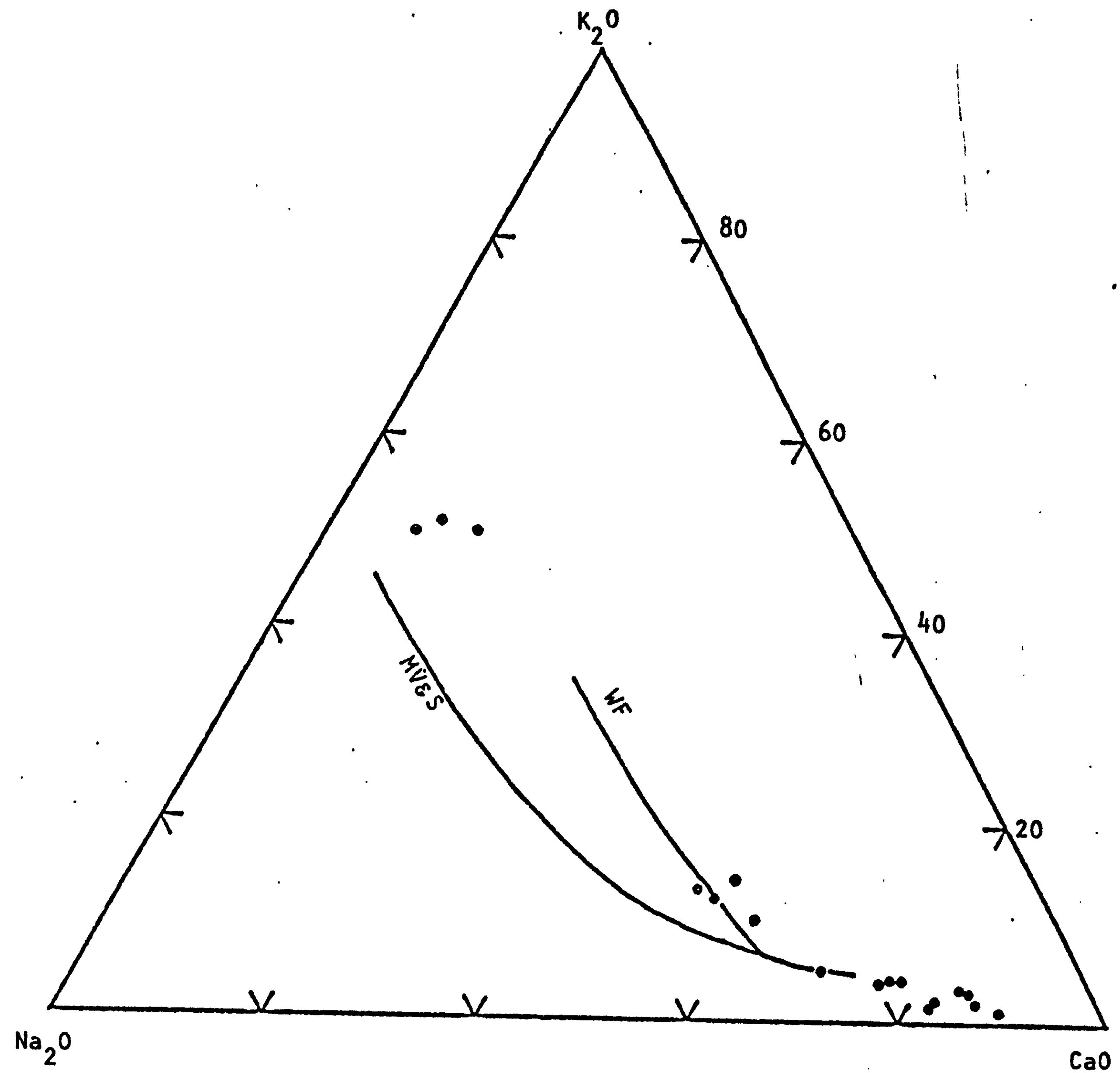
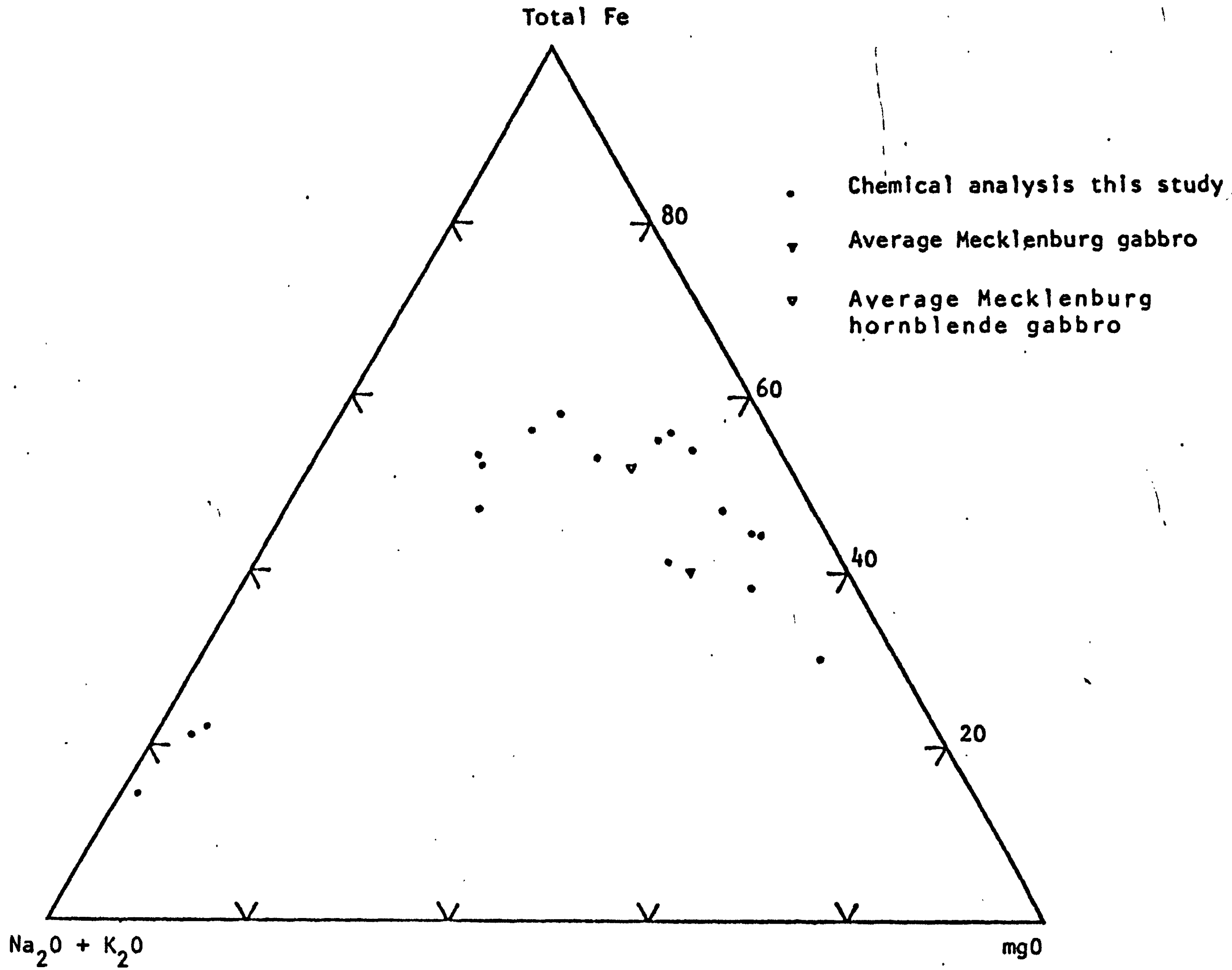

K$_2$O
80
60
40
20
Na$_2$O
CaO
MVES
WF

Figure 25. MgO - Total iron - total alkalies diagram of some rock analyses from southern Mecklenburg Co. and vicinity.


Total Fe
80
60
40
20
$Na_2O + K_2O$
mgO
Chemical analysis this study
Average Mecklenburg gabbro
Average Mecklenburg hornblende gabbro

island arc or continental subvolcanic province.

Ring structures

Ring structures in plutonic rocks may be attributed to 3 mechanisms, (1) surface cauldron subsidence, (2) subsurface cauldron subsidence, and (3) diapiric pluton emplacement.

Surface cauldron subsidence, or caldera collapse, is the subsidence of the roof of a high level magma chamber caused by the withdrawal of large amounts of supporting magma in cataclysmic eruptions. This topic is thoroughly covered by Smith (1965, 1979). He concludes that ring structures are the roots of calderas, and correlates the diameter of ring structures to the size and depth of emplacement of magma chambers.

Subsurface cauldron subsidence or stoping of large circular crustal blocks is thought to be caused by negative pressures in magma chambers and is advanced as a mechanism of pluton emplacement (Billings, 1972). Pitcher (1977) attributes the emplacement of the Peru Batholith to cauldron subsidence; Cobbing and Pitcher (1972) use the space mechanism of up-doming and erosion; and White and others (1974) believe that stoping and cauldron subsidence are not a primary mechanism of emplacement but a local phenomenon occurring near the top of the pluton.

Marsh (1979) explains pluton migration by stoping and viscous diapirism. In stoping, blocks of roof rock contaminate the magma chemically and thermally, and also rapidly impede its upward progress. In viscous diapirism, the wall rock is softened allowing roof rock to flow down along the side walls during upward migration of the magmas. This process would result in a granitic and, thus, highly radioactive, ring structure proportional to the size of the pluton - if gabbro magma, like the Mecklenburg, were emplaced in a granitic host.

Regardless of the cauldron subsidence mechanism that caused the ring structure, the brittle behavior of the country rock indicates that the magma chamber is in the upper levels of the crust. In all of the mechanisms the ring structure is directly related to the size of the magma chamber and may be correlated with depth of emplacement by Smith's (1979) diagrams.

Depth of emplacement of gabbros

The Concord and Mecklenburg gabbro complex both have ring structures 13 km (6 miles) in diameter. According to Smith (1979) the size of the ring structure suggests the gabbros may have been subsurface parts of stratovolcanos the size of Crater Lake, California, and that they were emplaced at a depth of 0 to 8 km. The three-dimensional shape of the Mt. Carmel complex is not known, accordingly its true diameter cannot be determined. If the diameter of the syenite ring is used as the diameter of the whole ring structure, 6 km, that would suggest that the Mt. Carmel volcano was the size of Krakatau, and the depth of emplacement would be from 0 to 6 km. This is within the 6 to 16 km range estimated by Medlin (1968).

Age of plutons in the study area

Old Plutonic supergroup

As there are no well defined plutons of the Old Plutonic supergroup in the study area, it is assumed that the tonalites, quartz diorites, and granodiorites of the Old Plutonic complex were the preexisting rocks into which the later Concord-Salisbury, and Landis supergroup plutons were emplaced. The age of these rocks is assumed to be that of the oldest dated plutons in the Charlotte belt, about 500 m.y.

Concord-Salisbury supergroup

The Mecklenburg-Weddington gabbro complex has been correlated with the Mt. Carmel and Concord gabbro complexes which have been dated. Medlin (1968) has established a minimal age for the Mt. Carmel gabbro of 380-386 m.y. These ages are from 3 K-Ar dates of biotite from diorite. Overstreet and Bell (1965a, p. 93) estimate the Concord gabbro to be 425 ± 110 m.y.

The Stallings granodiorite is a small elliptical pluton that is medium grained, and shows evidence of metamorphism. It is located on the east side of the Charlotte belt, like most the other to small Salisbury type plutons 55 km to the northeast and have ages of 413-386 m.y.

Eagle Lake granodiorite is located within the ring of high aeroradioactivity around the Mecklenburg gabbro that most likely is contemporaneous with the gabbro.

Landis supergroup

The Weddington granite is typical of the "big feldspar" post-metamorphic granites dated 325-265 m.y. that are mostly aligned along the western side of the northern Charlotte belt; but the Weddington occurs in the east, and marks the beginning of a different pattern of plutons south of the study area. These granites, the Landis and Churchland, are associated with a line of deep gravity lows. The Berryhill gravity low, in Charlotte West quadrangle is one of these and has been identified as a possible subsurface post-metamorphic granite (Wilson and Daniels, 1980).

Speer and others (1979) believe that coarse-grained "post-metamorphic" granite plutons form a supergroup, which is here called the

Landis supergroup, also that these granites are contemporaneous with "post-metamorphic" gabbros like the Mecklenburg. But structural relationships (fig. 26) in the Western part of the northern Charlotte belt suggest that "post-metamorphic" granites are emplaced below the Mecklenburg and other gabbros and, therefore, must be younger.

Charlotte belt composite batholith

Pitcher (1977) describes the overall sequence of magmatic intrusion in the Coastal Batholith of Peru as starting with gabbros and evolving through increasingly acidic granitoids to "big-feldspar" granites, the final magmatic phase. The complete process took 70 million years in Peru and emplaced hundreds of plutons at a sub-volcanic level. Each melt cell or superunit of plutons is thought to have taken 10 m.y. to emplace and resulted in a marked symmetry. The gabbros occupy the flanks of the batholith; tonalites and quartz diorites are internal; and in a median position are centered ring complexes and adamellites.

In the northern Charlotte belt, the gabbros are dispersed throughout the belt, but in South Carolina between the Mecklenburg and Mt.Carmel complexes, the gabbros occupy the center position (Long and others, 1975) (fig. 14(B). The spatial position of the supergroups within the exposed parts of the batholith, northern Charlotte belt and South Carolina segment, may be related to the level of erosion (fig. 26).

In the Charlotte belt, Landis group granitoids are more granitic in composition than the Concord-Salisbury group granitoids, and may have retained more of their volatile constituents. The Weddington granite is the best petrologic example of a Landis group granite in the study area. It is located just south of the Stallings granodiorite which has been tentatively classified as Salisbury type because of its composition, altered plagioclase, and associated volcanic rock. Both plutons are part of one large gravity low enclosed by the zero isogal (Plate 9).

The spatial relationship of the Stallings granodiorite and the Weddington granite seems to parallel that between the Olde Providence hornblende gabbro and the Weddington olivine gabbronorite. The hornblende gabbro, the Providence Church syenite and the Challis Lake mafic volcanics represent the upper levels of a mafic volcanic system. The Weddington troctolite and olivine gabbronorite may represent the lower level of the same system. Similarly, the Stallings granodiorite and the felsic volcanics associated with it may represent the upper levels of a silicic volcanic system. The Weddington granite represents a system in which most of the volatile constituents have been retained and a pluton that was blocked from reaching a higher level in the crust by the already emplaced Stallings granodiorite.

The negative gravity anomaly at Berryhill (Wilson and Daniels, 1980); the large pink felsic dikes cutting hornblende gabbro in the Arrowood quarry, and the spatial, compositional and temporal relationship of the Weddington gabbro and Weddington granite seem to indicate granitic magma of the Landis Group below a sheet-like carapace of gabbro in the northern Charlotte belt (fig. 26). The granitic magma may have leaked from the sides of the cooling gabbro sheet, or later tectonic events may have fractured the cooled gabbro producing conduits

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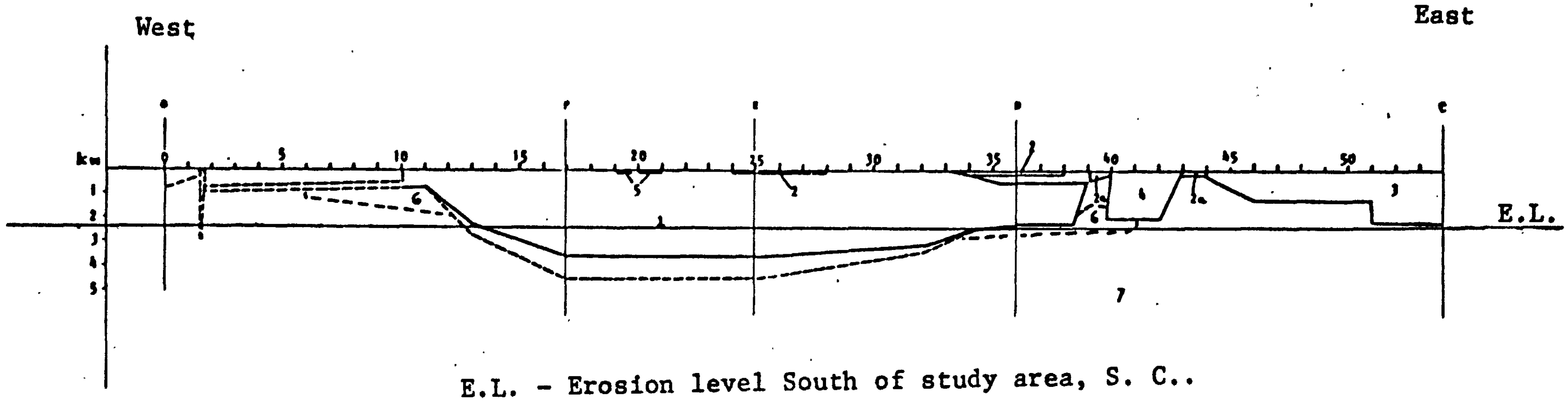
Figure 26. East - west structural cross section of the Charlotte belt composite batholith in southern Mecklenburg County and vicinity, North Carolina and South Carolina. (Plates 1 and 9)



E.L. - Erosion level South of study area, S. C..

1. Hornblende gabbro-
   Olivine gabbronorite
2. Metavolcanics
3. Carolina slate belt
   meta-igneous and metasediments
4. Granodiotite
5. Granodiorite

Landis supergroup 6,4

Concord-Salisbury supergroup 1,5,2

Old Plutonic supergroup 7

Old Plutonic complex 7,2a

Figure East - West structural cross section of the Charlotte belt composite batholith in southern Mecklenburg County, North Carolina.

for the development of granitic volcanic centers above the gabbro. The Salisbury group plutons may have been the shallow magma chambers of these volcanic systems which thermally metamorphosed the overlying volcanic and sedimentary rocks locally, and hydrothermally metamorphosed them regionally. The different levels of emplacement of the granitic rock suggest a plutonic stratigraphy for the Charlotte belt.

The composite batholith apparently was constructed over a period of about 200 m.y. as a single process operating during the entire time or as multiple processes. These results are the same as those reported by Cobbing and others (1977) for the Coastal Batholith of Peru - a series of magmatic pulses, beginning with emplacement of gabbro plutons and ending with the emplacement of "big feldspar" granites. Rb-Sr and K-Ar ages, alleged to date metamorphism and intrusion in the Piedmont, may only reflect the times of crustal uplift and cooling (Butler and Ragland, 1969, p. 179; Dallmyer, 1978). Therefore, the development of the composite batholith may have taken less time than indicated by the radiometric dates, and could have been the result of a single tectonic event or process.

A large subsurface mafic mass 80 km northeast of the study area in the Carolina slate belt could very well be the exposed equivalent of the gabbros of the northern Charlotte belt. This mass is expressed by high gravity and magnetic anomalies (fig. 14, 15). Some of its geophysical characteristics have been commented upon by Wilson and Daniels (1980), and Daniels and Zietz (1980). Anomalies similar to this occur east of the regional gravity gradient along the length of the southern Appalachians, and may trace the location of similar batholiths and their mafic complexes below Carolina slate belt metasediments and other rock.

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APPENDIX A

Geophysical methods

Aeroradioactivity Methods

Airborne radioactivity surveys are usually flown in conjunction with magnetic and other geophysical methods, if possible along parallel flight lines, at a constant elevation above the ground surface and at right angles to the strike of the rock structure. A scintillation counter, employing thallium activated sodium iodide crystals is normally used to detect and count gamma rays emitted from the three most common radioactive rock-forming elements, K^{40}, Uranium, and Thorium. A gamma ray spectrometer is a scintillation counter that differentiates between the energy levels of the gamma radiation and, therefore, has the capability of identifying the radioactive source element. Total count surveys record all gamma energies on a single channel; in most cases high count anomalies are due to outcrops of rocks with high K^{40} content such as granite and shale (Pemberton, 1967, p. 420 and 417). Radioactivity methods only reflect conditions to a depth of a few centimeters below the earth's surface. Ninety percent of gamma radiation is stopped by 0.3 m of common rock, 1.3 m of soil overburden, 0.6 m of water or 0.2 to 1.3 m of snow (Lang, 1970, p. 151).

Mapping radioactivity units is the preferred method of presenting data, but contoured data is effective in areas with high radioactivity contrast between rock units, and where radioactivity data will be compared or correlated with other contoured geophysical data (Bates, 1966, p. 69).

Magnetic Principles

Mafic igneous rocks are generally the most magnetic; granites and sedimentary rocks are the least magnetic.

The source of the earth's dipolar magnetic field is not yet well understood, but the major portion of the field is believed to come from an internal source composed of two parts: (1) a main field originating in the core of the earth, and (2) another component of the field from the upper crust. The main field is thought to be generated by a complex mechanism in the deep core. Temperatures in the core are much greater than the Curie point (578′ C) of magnetite, the most common ferromagnetic mineral in rocks (Nagata, 1961, p. 81). The crustal component is composed of rocks at temperatures below the Curie point of magnetite. Magnetic fields in these rocks are generated by induction and normal remanent magnetism, and depend on the magnetic character and distribution of ferromagnetic minerals which are related to the composition and the history of formation of the rock.

Ferromagnetic minerals in rocks are: the iron-titanium oxide group which contains the solid solution series ulvospinel (Fe_2TiO_4), magnetite (Fe_3O_4) ilmenite ($FeTiO_3$) hematite (Fe_2O_3); and the iron sulfide group of which pyrrhotite (FeS_{1+x}) is the only important member. All of these minerals have magnetic properties which vary with the chemical composition. They have been described by Nagata (1961).

In the ulvospinel-magnetite series, magnetite is the most common member; the Curie temperature varies from 578°C (magnetite) to -150°C (ulvospinel); the intensity of magnetization decreases directly with increasing ulvospinel component. The finer the grain size, the higher the stability of remanent magnetism. Within the ilmenite-hematite series, the Curie temperature also decreases with increasing ilmenite content; the degree of magnetization is weak; but the remanent magnetism is very stable. Pyrrohotite has a Curie temperature of 320′C, and the stability of remanent magnetizaton is relatively poor.

Magnetic Induction

Magnetic induction is an important property of rocks that contain ferromagnetic minerals. When placed in a magnetic field, such as the earth's field, these rocks acquire a magnetism of their own. A part of this magnetism is lost if the field is removed. Such magnetization is said to be induced by the applied field and is proportional to, and parallel to the applied field.

Magnetic Susceptibility

Induced magnetization (Ji) in a material is proportional and parallel to the applied field (H). The magnetic character of the material is such that k^1=Ji/H where the factor k^1 is the magnetic susceptibility of the material or rock. The magnetic field created by the induced magnetization is added to the strength of the applied field and in the case of rocks of the uper crust may cause areas of anomalous magnetic values.

Magnetic susceptibility in rocks is not only dependent upon the amount of magnetic minerals that they contain, but also on the size and shape of the magnetic mineral grains; their mode of dispersion; and their chemical composition. Susceptibility can, therefore, vary widely within a single rock body. It is, therefore, necesary to make a collection of many carefully selected samples from a particular formation or rock body to determine average susceptibility. Basic igneous rocks usually have the highest magnetic susceptibility.

Natural Remanent Magnetism (NRM)

In some rocks, when the applied magnetic field is removed or changed, some of the original magnetization is retained. This retained magnetization is called the remanent magnetization. Most of the rocks of the upper crust have a natural remanent magnetization (NRM). NRM in rocks depends on the nature of the ferromagnetic minerals in the rock, the strength of the geomagnetic field at the time of origin, and the later geologic history of the rock body. There are several types of remanent magnetism included in the NRM of rocks. The most important, and most commonly referred to, are thermoremanent magnetism (TRM), isothermal remanent magnetism (IRM), viscous remanent magnetism (VRM), and chemical remanent magnetism (CRM).

Thermoremanent Magnetism (TRM) the Curie point, to some cooler ambient temperature. Most of the TRM is usually acquired between 150′C to 100′C below the Curie Point because of solid solution with other minerals (Sharma, 1976, p. 198); it is parallel to the applied field and it is proportional to the strength of the applied field. The total TRM is usually the sum of partial remanent magnetizations acquired during cooling events (Sharma, 1976, p. 198). The stability of TRM usually decreases with increasing grain size and is much stronger and more stable than later secondary magnetizations, such as IRM and VRM.

Isothermal Remanent Magnetization (IRM) is that component acquired by rocks at constant temperature, when an external field is applied and then removed after a short time. IRM is important in surface rocks that have been struck by lightning. The effects of lightning are local and can be detected if sampling is systematic and covers a sufficient area.

Viscous Remanent Magnetization (VRM) is an isothermal cumulative magnetization that occurs during long exposure of rocks in an ambient magnetic field. The intensity and stability of VRM is a function of time. The NRM's of some rocks have been reported as being appreciably altered after only a few weeks of laboratory storage (Sharma, 1976, p. 198). Rocks with such large NRM components of "soft" or viscuous magnetism are unsuited to paleomagnetic work.

Chemical Remanent Magnetism (CRM) is acquired from the earth's field at the time of nucleation and growth, or, recrystallization of fine magnetic grains by sedimentary or metamorphic chemical recreations at temperatures below the Curie point. The stability of CRM is similar to that of TRM but the intensity is generally less.

The Konigsberger ratio (Q)

The Konigsberger ratio (Q) is often used as a numerical parameter in the study of magnetism in rocks. Q is equal to the ratio of NRM (Jr) to magnetism induced by the present earth magnetic field (Ji) at the sample location (Q=Jr/Ji). Because the original NRM is weakened with time by various relaxation processes, older rocks usually have smaller Q values (Sharma, 1976, p. 202). Q ratios for some rocks in the study area are listed in Appendix D.

Remanent magnetism is particularly large in igneous rocks and often exceeds the intensity of induced magnetization. These rocks have Q values greater than 1. Interpretation of magnetic anomalies produced by these rocks must consider the direction and magnitude of NRM and is discussed in Zietz and Andreasen (1966). An analysis of NRM or paleomagnetism requires numerous samples, partial demagnetization or "magnetic cleaning" to remove soft VRM, and the use of a spinner or astatic magnetometer to determine the direction and magnitude of the hard component of NRM and TRM.

APPENDIX B

Gravity Stations

STA.	-	Station Number
LAT.	-	Latitude
LONG.	-	Longitude
ELEV.(F)	-	Elevation in feet
OBS.G	-	Observed gravity
FAA	-	Free Air gravity, in milligals
BA 2.67	-	Bouguer gravity in milligals at 2.67 g/cc density
BA 2.80	-	Bouguer gravity in milligals at 2.80 g/cc density

Minus signs denote negative Bouguer gravity values.

Gravity stations without numbers are from the Defense Mapping Agency

STA.	LAT	LONG	ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
524	35 8.00	80 27.90	566.0	2	1718.41	27.42	8.11	7.17
542	35 13.39	80 28.89	516.0	2	1726.33	23.00	5.39	4.53
523	35 7.97	80 29.40	524.0	3	1719.91	25.02	7.14	6.27
788	35 4.88	80 30.03	564.0	2	1715.05	28.30	9.05	8.12
903	35 9.37	80 30.06	613.0	3	1715.41	26.91	5.99	4.97
515	35 14.98	80 30.11	523.0	1	1728.11	23.18	5.33	4.47
909	35 12.80	80 30.12	508.0	3	1724.99	21.74	4.41	3.57
793	35 6.14	80 30.18	595.0	2	1714.14	28.53	8.22	7.23
780	35 0.60	80 30.30	563.0	2	1710.81	30.03	10.82	9.88
904	35 10.12	80 30.34	554.0	2	1719.02	23.90	5.00	4.08
785	35 2.31	80 30.36	536.0	2	1714.30	28.56	10.27	9.38
901	35 7.93	80 30.37	572.0	2	1716.39	26.07	6.55	5.60
522	35 8.54	80 30.42	556.0	3	1717.70	25.01	6.04	5.12
908	35 11.89	80 30.47	476.0	2	1725.91	20.94	4.70	3.91
516	35 13.70	80 30.52	534.0	2	1725.01	22.94	4.71	3.83
907	35 11.16	80 30.66	465.0	2	1725.63	20.67	4.80	4.03
784	35 1.45	80 30.70	510.0	2	1714.75	27.78	10.38	9.53
791	35 6.50	80 30.70	592.0	2	1714.19	27.78	7.58	6.59
792	35 7.28	80 30.70	590.0	2	1714.90	27.20	7.07	6.09
910	35 14.32	80 30.76	524.0	3	1727.10	23.20	5.32	4.45
786	35 2.99	80 30.80	584.0	2	1711.95	29.76	9.84	8.87
787	35 4.12	80 30.94	590.0	2	1712.66	29.43	9.30	8.32
905	35 10.63	80 30.94	492.0	2	1722.80	21.13	4.34	3.52
790	35 5.94	80 30.98	617.0	2	1712.14	28.87	7.82	6.79
789	35 5.23	80 30.99	610.0	2	1711.98	29.06	8.25	7.23
781	35 0.13	80 31.17	579.0	2	1709.26	30.65	10.89	9.93
899	35 8.36	80 31.23	577.0	2	1715.76	25.30	5.61	4.66
517	35 12.63	80 31.31	523.0	1	1724.14	22.55	4.70	3.83
902	35 7.55	80 31.36	582.0	3	1714.86	26.02	6.17	5.20
900	35 9.00	80 31.44	556.0	3	1717.36	24.02	5.04	4.12
926	35 13.34	80 31.57	561.0	2	1723.90	24.88	5.73	4.80
906	35 10.02	80 31.64	500.0	5	1721.56	21.50	4.44	3.61
795	35 6.83	80 31.73	602.0	2	1712.84	26.90	6.36	5.36
491	35 3.50	80 31.79	608.0	1	1710.24	29.59	8.84	7.83
492	35 4.52	80 31.84	626.0	1	1710.03	29.63	8.27	7.23

STA.	LAT		LONG		ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
783	35	1.33	80	31.87	567.0	2	1710.95	29.51	10.16	9.22
490	35	2.41	80	31.90	575.0	2	1711.42	29.20	9.58	8.63
782	35	0.49	80	31.97	571.0	4	1709.80	29.93	10.45	9.50
770	34	59.25	80	31.98	584.0	5	1708.26	31.37	11.52	10.47
518	35	11.40	80	32.00	494.0	3	1723.87	21.29	4.44	3.62
493	35	5.64	80	32.03	635.0	2	1710.26	29.11	7.44	6.39
514	35	14.97	80	32.19	620.0	1	1726.15	30.36	9.20	8.17
796	35	6.22	80	32.20	619.0	1	1710.96	27.49	6.37	5.34
495	35	7.48	80	32.20	571.0	3	1714.67	24.89	5.41	4.46
927	35	12.43	80	32.21	502.0	4	1725.86	22.57	5.44	4.61
494	35	6.62	80	32.25	607.0	2	1711.99	26.82	6.11	5.10
496	35	8.30	80	32.26	530.0	2	1717.77	22.97	4.89	4.01
A490	35	1.85	80	32.28	571.0	2	1711.00	29.20	9.72	8.77
925	35	13.22	80	32.36	556.0	2	1725.03	25.71	6.73	5.81
521	35	9.71	80	32.37	520.0	2	1719.86	22.13	4.39	3.52
935	35	10.80	80	32.45	486.0	1	1723.25	20.78	4.19	3.39
489	35	1.16	80	32.52	564.0	2	1710.51	29.03	9.79	8.85
826	35	0.23	80	32.63	568.0	2	1709.43	29.65	10.26	9.32
912	35	14.00	80	32.65	581.0	2	1727.29	29.21	9.38	8.42
942	35	7.86	80	32.79	568.0	2	1714.88	24.29	4.91	3.96
794	35	5.86	80	32.82	613.0	2	1710.41	26.89	5.97	4.95
A518	35	11.46	80	32.85	545.0	5	1721.32	23.46	4.86	3.96
821	35	5.33	80	32.89	631.0	2	1709.18	28.10	6.57	5.52
911	35	14.94	80	32.89	658.0	1	1726.35	34.18	11.73	10.63
824	35	3.07	80	32.90	612.0	2	1709.19	29.52	8.64	7.62
800	35	7.10	80	32.92	570.0	5	1713.90	24.57	5.12	4.18
825	35	2.10	80	33.09	572.0	2	1710.55	28.49	8.98	8.03
497	35	9.04	80	33.18	528.0	2	1718.47	22.44	4.43	3.55
943	35	9.88	80	33.21	560.0	5	1718.01	23.80	4.69	3.76
797	35	6.47	80	33.29	593.0	2	1711.92	25.65	5.41	4.43
823	35	4.10	80	33.33	625.0	2	1708.86	28.95	7.62	6.59
488	35	0.26	80	33.35	594.0	3	1707.82	30.43	10.17	9.18
924	35	12.80	80	33.39	582.0	2	1725.47	29.18	9.32	8.36
836	35	0.98	80	37.43	674.0	3	1699.54	28.67	5.67	4.55
913	35	13.60	80	33.53	600.0	2	1728.56	32.84	12.36	11.37

STA.	LAT	LONG	ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
799	35 7.62	80 33.58	550.0	5	1715.32	23.38	4.61	3.70
803	35 1.30	80 33.59	558.0	3	1710.59	28.35	9.31	8.38
A803	35 1.30	80 33.59	558.0	2	1710.49	28.25	9.21	8.28
519	35 11.78	80 33.62	576.0	2	1721.92	26.52	6.87	5.91
822	35 4.71	80 33.14	641.0	2	1708.36	29.10	7.22	6.16
798	35 6.55	80 33.75	575.0	1	1712.84	24.76	5.14	4.18
801	35 6.91	80 33.87	585.0	2	1712.64	24.99	5.03	4.06
930	35 10.78	80 33.92	561.0	4	1719.60	24.21	5.06	4.13
820	35 5.07	80 33.97	619.0	2	1709.10	27.26	6.13	5.11
934	35 8.66	80 33.97	559.0	2	1715.75	23.17	4.10	3.17
804	35 2.53	80 34.17	597.0	2	1708.58	28.27	7.90	6.91
914	35 14.24	80 34.21	668.0	2	1728.03	37.79	15.00	13.89
827	35 1.75	80 34.23	585.0	2	1708.54	28.20	8.24	7.27
819	35 5.76	80 34.28	611.0	2	1709.90	26.33	5.48	4.46
A498	35 9.68	80 34.28	590.0	5	1716.57	25.47	5.33	4.35
A498	35 9.68	80 34.28	590.0	5	1716.59	25.49	5.35	4.37
A931	35 9.10	80 34.33	591.0	2	1715.30	25.11	4.95	3.97
487	35 0.96	80 34.34	595.0	3	1707.57	29.29	8.99	8.00
806	35 3.67	80 34.34	631.0	2	1707.16	28.43	6.90	5.85
933	35 8.04	80 34.34	558.0	2	1714.78	22.99	3.95	3.02
513	35 14.92	80 34.35	722.0	1	1725.59	39.46	14.83	13.63
928	35 13.46	80 34.40	636.0	2	1728.40	36.26	14.56	13.50
B931	35 9.27	80 34.49	610.0	5	1714.09	25.44	4.63	3.62
B826	35 0.40	80 34.62	615.0	2	1705.84	30.24	9.25	8.23
564	35 4.67	80 34.64	608.0	2	1708.87	26.56	5.81	4.80
802	35 7.43	80 34.65	528.0	2	1715.90	22.15	4.14	3.26
929	35 10.70	80 34.66	574.0	2	1719.96	25.90	6.32	5.36
498	35 9.81	80 34.72	578.0	2	1716.88	24.47	4.74	3.78
923	35 11.80	80 34.76	696.0	2	1717.23	33.09	9.34	8.18
520	35 12.72	80 34.78	606.0	2	1727.85	33.94	13.26	12.25
828	35 2.39	80 35.03	610.0	5	1706.96	28.07	7.25	6.24
931	35 8.94	80 35.05	587.0	2	1714.96	24.62	4.59	3.62
817	35 6.35	80 35.07	594.0	2	1710.67	24.66	4.39	3.40
818	35 5.37	80 35.12	628.0	2	1707.80	26.38	4.95	3.91

STA.	LAT	LONG	ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
915	35 13.77	80 35.13	639.0	3	1730.19	37.89	16.08	15.02
486	35 1.58	80 35.20	635.0	2	1704.90	29.51	7.84	6.78
932	35 8.14	80 35.22	570.0	2	1713.76	22.95	3.50	2.56
565	35 6.96	80 35.24	541.0	2	1714.12	22.26	3.80	2.90
919	35 11.69	80 35.36	624.0	3	1725.07	34.31	13.02	11.98
830	35 0.12	80 35.39	633.0	2	1704.26	30.74	9.14	8.09
807	35 4.48	80 35.44	615.0	2	1707.75	26.36	5.38	4.36
769	35 1.03	80 35.52	627.0	1	1704.91	29.54	8.14	7.10
B512	35 15.63	80 35.53	659.0	1	1732.99	39.93	17.45	16.35
A512	35 14.45	80 35.58	727.0	1	1725.77	40.78	15.97	14.77
922	35 11.37	80 35.65	703.0	2	1716.81	33.94	9.95	8.78
816	35 6.08	80 35.80	618.0	5	1707.17	23.80	2.71	1.69
920	35 11.17	80 37.30	713.0	1	1717.58	35.93	11.60	10.41
917	35 12.84	80 35.88	727.0	2	1721.46	38.76	13.95	12.74
512	35 14.04	80 35.94	709.0	2	1726.55	40.45	16.25	15.08
936	35 7.59	80 36.03	589.0	2	1711.74	23.50	3.40	2.42
815	35 6.85	80 36.09	590.0	5	1710.69	23.59	3.46	2.48
941	35 9.53	80 36.09	609.0	2	1714.33	25.23	4.45	3.44
809	35 3.76	80 36.10	628.0	2	1705.42	26.28	4.86	3.81
811	35 5.30	80 36.11	633.0	5	1706.45	25.60	4.00	2.95
485	35 2.25	80 36.12	645.0	2	1703.86	28.46	6.45	5.38
938	35 8.58	80 36.19	636.0	2	1710.25	25.03	3.33	2.27
808	35 3.20	80 36.22	652.0	2	1703.55	27.46	5.21	4.13
499	35 10.25	80 36.30	650.0	2	1715.69	29.42	7.24	6.16
921	35 11.02	80 36.41	725.0	2	1715.19	34.88	10.14	8.94
829	35 0.83	80 36.43	653.0	2	1702.39	29.75	7.46	6.38
919	35 11.73	80 36.53	614.0	3	1724.96	33.20	12.25	11.23
918	35 12.45	80 36.69	704.0	1	1722.00	37.69	13.67	12.50
A919	35 12.08	80 36.71	657.0	2	1724.02	35.82	13.40	12.31
940	35 9.20	80 36.80	654.0	4	1711.39	26.99	4.67	3.58
C512	35 15.41	80 36.82	676.0	2	1732.57	41.42	18.35	17.23
937	35 8.16	80 36.86	638.0	2	1708.73	24.30	2.53	1.47
916	35 13.54	80 36.89	775.0	1	1720.91	41.73	15.28	14.00
837	35 1.86	80 37.00	666.0	2	1701.23	28.35	5.63	4.52
813	35 5.72	80 37.00	640.0	5	1706.26	25.47	3.63	2.57

STA.	LAT		LONG		ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
939	35	9.38	80	37.07	687.0	2	1711.48	29.92	6.48	5.34
831	35	0.21	80	37.16	643.0	2	1701.58	28.88	6.94	5.87
A920	35	11.70	80	37.20	624.0	3	1724.78	34.01	12.72	11.68
810	35	4.30	80	37.26	641.0	2	1703.97	25.29	3.42	2.35
851	35	6.95	80	37.28	623.0	2	1709.06	24.93	3.68	2.64
814	35	6.22	80	37.41	634.0	2	1708.87	26.81	5.18	4.12
944	35	10.08	80	37.62	715.0	2	1712.22	32.30	7.90	6.72
500	35	10.58	80	37.66	773.0	2	1712.10	36.93	10.56	9.27
484	35	3.15	80	37.34	641.0	3	1702.79	25.73	3.86	2.79
B511	35	14.85	80	37.70	723.0	1	1725.17	39.23	14.56	13.36
843	35	2.25	80	37.73	666.0	2	1700.31	26.88	4.16	3.05
812	35	5.81	80	37.74	649.0	2	1707.28	27.21	5.06	3.98
566	35	8.78	80	37.80	703.0	1	1708.85	29.65	5.66	4.49
511	35	12.95	80	37.81	736.0	2	1722.95	40.94	15.82	14.60
945	35	7.84	80	37.86	608.0	3	1711.18	24.37	3.63	2.62
510	35	12.24	80	37.98	648.0	3	1722.78	33.50	11.39	10.31
A511	35	14.10	80	38.00	766.0	2	1722.59	41.77	15.63	14.35
D511	35	13.40	80	38.09	781.0	2	1721.00	42.58	15.93	14.64
482	35	3.73	80	38.12	642.0	2	1702.77	24.99	3.08	2.01
832	35	0.49	80	38.20	655.0	2	1699.51	27.54	5.19	4.10
846	35	4.55	80	38.20	635.0	2	1704.35	24.74	3.08	2.02
852	35	6.56	80	38.20	659.0	2	1705.41	25.22	2.73	1.64
C511	35	15.24	80	38.20	691.0	2	1730.14	40.64	17.06	15.91
884	35	9.42	80	38.33	704.0	1	1712.20	32.18	8.16	6.99
850	35	5.47	80	38.36	662.0	2	1703.71	25.34	2.75	1.65
509	35	11.43	80	38.44	762.0	2	1715.48	38.07	12.07	10.80
838	35	1.83	80	38.66	649.C	2	1699.76	25.33	3.19	2.11
567	35	7.18	80	38.75	670.0	2	1706.21	26.17	3.31	2.20
842	35	2.73	80	38.79	663.0	1	1699.54	25.15	2.53	1.43
885	35	10.54	80	38.84	780.0	1	1711.72	37.27	10.65	9.35
883	35	8.82	80	38.88	677.0	2	1711.96	30.25	7.15	6.03
773	35	14.40	80	39.00	626.0	3	1730.17	35.75	14.39	13.35
501	35	11.03	80	39.06	773.0	2	1713.87	38.07	11.69	10.40
888	35	12.17	80	39.07	752.0	2	1719.16	39.76	14.10	12.85
483	35	4.57	80	39.14	647.0	3	1702.30	23.80	1.72	0.65

STA.	LAT	LONG	ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
849	35 5.74	80 39.18	709.0	2	1699.75	25.42	1.23	0.05
833	35 0.30	80 39.25	632.0	2	1699.51	25.64	4.08	3.03
839	35 2.35	80 39.30	644.0	2	1701.40	25.76	3.78	2.71
844	35 3.36	80 39.50	664.0	2	1700.06	24.87	2.21	1.11
890	35 13.04	80 39.30	780.0	5	1720.57	42.57	15.95	14.65
882	35 8.45	80 39.51	667.0	2	1712.31	30.19	7.43	6.32
835	35 1.13	80 39.54	618.0	2	1700.03	23.67	2.59	1.56
840	35 1.76	80 39.58	642.0	1	1699.09	24.10	2.19	1.12
A773	35 14.53	80 39.80	734.0	2	1723.02	38.58	13.53	12.31
772	35 14.90	80 39.39	712.0	2	1726.26	39.22	14.93	13.74
848	35 6.43	80 39.88	699.0	2	1700.92	24.68	0.83	-0.33
502	35 10.07	80 39.90	776.0	2	1711.13	36.97	10.49	9.20
887	35 11.20	80 39.92	771.0	2	1715.50	39.26	12.95	11.67
845	35 3.74	80 39.95	670.0	5	1698.47	23.30	0.44	-0.67
834	35 0.37	80 39.98	603.0	2	1699.74	23.05	2.47	1.47
478	35 4.67	80 40.12	697.0	1	1697.76	23.82	0.04	-1.12
478	35 4.67	80 40.12	697.0	1	1697.75	23.81	0.03	-1.13
775	35 13.40	80 40.18	677.0	2	1725.58	37.38	14.28	13.15
847	35 5.58	80 40.22	687.0	2	1699.08	22.91	-0.53	-1.67
889	35 12.23	80 40.22	801.0	2	1717.51	42.63	15.30	13.97
841	35 1.74	80 40.23	644.0	5	1699.84	25.07	3.09	2.02
503	35 9.49	80 40.34	773.0	2	1709.78	36.16	9.78	8.50
853	35 7.04	80 40.37	753.0	2	1699.68	27.65	1.96	0.71
771	35 14.79	80 40.41	726.0	2	1724.02	38.46	13.68	12.48
481	35 1.11	80 40.42	631.0	1	1698.96	23.85	2.32	1.27
774	35 13.94	80 40.44	762.0	2	1720.01	38.41	12.41	11.14
886	35 10.75	80 40.54	697.0	2	1717.49	34.93	11.15	9.99
880	35 2.90	80 40.60	640.0	2	1699.04	22.25	0.41	-0.66
477	35 5.70	80 40.79	754.0	2	1692.86	22.82	-2.91	-4.16
504	35 8.88	80 40.84	773.0	2	1708.68	35.92	9.54	8.26
879	35 3.75	80 40.92	719.0	2	1693.52	22.95	-1.58	-2.78
541	35 12.65	80 40.95	766.0	2	1720.17	41.41	15.27	14.00
A889	35 11.72	80 41.00	791.0	2	1716.43	41.33	14.34	13.03
505	35 8.24	80 41.01	783.0	1	1705.41	34.50	7.78	6.48

STA.	LAT	LONG	ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
872	35 0.32	80 41.08	567.0	2	1700.26	20.25	0.90	-0.04
861	35 4.43	80 41.09	726.0	2	1694.44	23.57	-1.20	-2.41
776	35 13.38	80 41.12	776.0	2	1718.81	39.95	13.47	12.18
873	35 1.17	80 41.29	630.0	5	1696.92	21.63	0.14	-0.91
762	35 14.60	80 41.48	709.0	2	1723.57	36.67	12.48	11.30
508	35 10.86	80 41.53	749.0	2	1716.28	38.46	12.90	11.65
480	35 1.98	80 41.58	667.0	2	1695.21	22.26	-0.50	-1.60
476	35 6.15	80 41.58	769.0	2	1694.80	25.54	-0.70	-1.98
854	35 5.67	80 41.79	752.0	2	1692.98	22.79	-2.87	-4.12
855	35 4.99	80 41.82	776.0	2	1689.97	23.00	-3.48	-4.77
898	35 8.64	80 41.85	772.0	2	1707.79	35.28	8.94	7.65
475	35 7.15	80 41.92	767.0	1	1700.86	29.99	3.81	2.54
862	35 4.20	80 41.96	716.0	2	1695.11	23.62	-0.81	-2.00
878	35 3.29	80 41.98	709.0	2	1694.07	23.21	-0.98	-2.16
777	35 13.25	80 42.01	777.0	2	1717.40	38.82	12.30	11.01
871	35 0.06	80 42.20	617.0	1	1696.13	21.20	0.14	-0.88
763	35 13.95	80 42.26	753.0	2	1720.51	38.68	12.99	11.73
896	35 11.64	80 42.46	695.0	2	1722.81	38.80	15.09	13.93
874	35 1.23	80 42.36	586.0	2	1698.28	18.77	-1.22	-2.20
897	35 9.98	80 41.38	659.0	3	1719.32	34.27	11.79	10.69
766	35 10.40	80 42.42	735.0	1	1715.94	37.45	12.37	11.15
A891	35 12.52	80 42.45	721.0	2	1723.03	40.21	15.61	14.41
805	35 2.99	80 34.97	629.0	2	1706.16	28.20	6.74	5.70
891	35 12.54	80 42.49	721.0	2	1721.63	38.79	14.19	12.99
474	35 7.07	80 42.54	753.0	2	1702.38	30.31	4.61	3.36
856	35 6.20	80 42.60	716.0	2	1699.82	25.50	1.07	-0.12
863	35 4.03	80 42.62	665.0	2	1697.82	21.78	-0.91	-2.02
860	35 5.14	80 42.70	759.0	2	1692.23	23.45	-2.45	-3.71
767	35 9.50	80 42.80	630.0	1	1719.83	32.74	11.24	10.20
A767	35 9.50	80 42.80	630.0	1	1719.71	32.63	11.13	10.08
877	35 2.85	80 42.82	670.0	5	1694.94	21.04	-1.82	-2.94
778	35 14.17	80 43.00	725.0	2	1721.86	37.08	12.34	11.13
768	35 8.05	80 43.04	642.0	1	1714.58	30.67	8.77	7.70
A768	35 8.05	80 43.04	640.0	1	1714.59	30.50	8.66	7.60
779	35 14.84	80 43.04	735.0	2	1723.36	38.57	13.49	12.27

STA.	LAT		LONG		ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
876	35	1.90	80	43.05	657.0	3	1693.53	19.75	-2.67	-3.76
870	35	0.04	80	43.14	562.0	2	1698.05	17.97	-1.20	-2.14
875	35	1.24	80	43.33	671.0	2	1691.19	19.66	-3.23	-4.35
507	35	8.73	80	43.39	668.0	3	1711.20	28.78	5.99	4.88
946	35	9.56	80	43.50	691.0	2	1716.37	34.93	11.36	10.21
764	35	13.38	80	43.50	791.0	1	1716.53	39.08	12.09	10.78
540	35	12.13	80	43.60	781.0	1	1716.44	39.82	13.17	11.88
540	35	12.12	80	43.61	781.0	1	1716.51	39.91	13.26	11.96
479	35	3.59	80	43.62	741.0	2	1690.13	21.86	-3.43	-4.66
857	35	6.03	80	43.74	646.0	2	1705.78	25.11	3.07	2.00
864	35	4.16	80	43.75	750.0	2	1691.88	23.65	-1.94	-3.19
765	35	10.70	80	43.76	718.0	2	1717.22	36.71	12.21	11.02
858	35	5.40	80	43.99	740.0	2	1697.90	26.97	1.72	0.49
869	35	0.11	80	44.00	640.0	1	1691.47	18.62	-3.21	-4.28
865	35	3.15	80	44.22	748.0	2	1689.51	22.52	-3.00	-4.24
892	35	14.56	80	44.27	786.0	2	1718.13	38.54	11.72	10.41
895	35	11.55	80	44.36	724.0	2	1719.15	38.00	13.29	12.09
866	35	2.45	80	44.47	730.0	2	1689.56	21.87	-3.04	-4.26
506	35	9.85	80	44.47	635.0	2	1719.42	32.31	10.64	9.59
868	35	0.73	80	44.55	662.0	2	1690.07	18.42	-4.17	-5.27
859	35	4.59	80	44.56	736.0	2	1694.44	24.28	-0.84	-2.06
473	35	6.95	80	44.60	723.0	2	1705.28	30.56	5.89	4.69
893	35	13.43	80	44.71	777.0	2	1717.60	38.76	12.25	10.96
867	35	1.67	80	44.72	727.0	2	1687.61	20.74	-4.06	-5.27
947	35	10.88	80	44.85	738.0	2	1715.80	36.91	11.73	10.50
948	35	8.25	80	44.96	695.0	4	1711.72	32.52	8.80	7.65
894	35	12.24	80	45.01	742.0	3	1719.76	39.32	14.00	12.77
1008	35	2.30	80	45.02	719.0	2	1692.62	24.10	-0.43	-1.63
952	35	14.85	80	45.16	749.0	2	1719.29	35.80	10.24	9.00
472	35	6.86	80	45.22	725.0	1	1705.18	30.77	6.04	4.83
975	35	7.67	80	45.33	648.0	2	1710.99	28.19	6.08	5.00
1029	35	6.17	80	45.36	673.0	2	1706.83	28.51	5.55	4.43
1013	35	3.89	80	45.39	692.0	4	1699.45	26.15	2.53	1.38
1011	35	4.66	80	45.39	712.0	2	1699.00	26.49	2.19	1.01
973	35	8.92	80	45.60	577.0	2	1721.53	30.28	10.59	9.63

STA.	LAT	LONG	ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
164	35 12.10	80 45.64	772.0	2	1717.64	40.22	13.88	12.60
167	35 14.06	80 45.64	752.0	2	1718.65	36.57	10.91	9.66
1012	35 5.30	80 45.65	660.0	5	1704.81	26.50	3.98	2.88
971	35 9.93	80 45.74	696.0	4	1716.84	35.35	11.60	10.45
468	35 1.27	80 45.78	721.0	1	1689.50	22.64	-1.97	-3.16
165	35 12.72	80 45.78	770.0	2	1716.42	37.93	11.66	10.38
1007	35 0.69	80 45.96	711.0	1	1688.20	21.21	-3.05	-4.23
471	35 6.38	80 46.00	687.0	1	1709.97	32.67	9.23	8.09
469	35 0.36	80 46.03	701.0	2	1688.10	20.64	-3.28	-4.44
467	35 2.17	80 46.08	621.0	2	1707.94	30.39	9.20	8.17
470	35 2.89	80 46.17	702.0	3	1706.86	35.91	11.96	10.79
974	35 7.85	80 46.18	628.0	2	1715.36	30.42	8.99	7.95
B466	35 3.86	80 46.20	710.0	1	1702.57	31.00	6.77	5.59
146	35 10.56	80 46.24	693.0	1	1717.65	34.98	11.33	10.18
A146	35 10.56	80 46.24	693.0	1	1717.60	34.94	11.29	10.14
466	35 4.23	80 46.30	695.0	2	1704.26	30.76	7.04	5.89
A466	35 4.74	80 46.34	669.0	1	1707.48	30.81	7.98	6.87
465	35 5.30	80 46.48	574.0	2	1715.95	29.54	9.96	9.00
951	35 14.19	80 46.54	760.0	2	1719.95	38.43	12.50	11.24
1031	35 5.78	80 48.60	629.0	2	1722.70	40.80	19.33	18.29
1010	35 3.43	80 46.66	650.0	5	1710.69	34.09	11.91	10.83
1005	35 0.68	80 46.67	713.0	2	1691.07	24.29	-0.04	-1.23
968	35 11.35	80 46.71	757.0	3	1714.98	37.22	11.39	10.13
214	35 5.97	80 46.73	653.0	5	1717.91	37.99	15.71	14.62
970	35 9.62	80 46.76	746.0	3	1712.31	35.96	10.51	9.27
464	35 7.04	80 46.77	628.0	2	1718.77	34.98	13.55	12.51
166	35 13.32	80 46.78	721.0	2	1718.90	34.96	10.35	9.16
956	35 12.40	80 46.80	724.0	3	1718.26	35.90	11.20	10.00
C466	35 4.13	80 46.85	666.0	2	1709.80	33.71	10.99	9.88
972	35 8.78	80 46.87	657.0	3	1716.60	33.07	10.66	9.56
950	35 14.97	80 46.88	772.0	2	1716.43	34.94	8.59	7.31
1009	35 1.66	80 47.07	640.0	5	1708.49	33.45	11.62	10.55
A213	35 5.20	80 47.19	604.0	2	1717.53	34.09	13.48	12.47
463	35 7.69	80 47.25	609.0	2	1717.10	30.61	9.83	8.81

STA.	LAT	LONG	ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
1014	35 3.81	80 47.29	656.0	1	1712.11	35.54	13.15	12.06
1014	35 3.81	80 47.29	655.0	1	1712.18	35.50	13.15	12.06
1006	35 1.18	80 47.30	672.0	2	1703.92	32.57	9.64	8.53
1015	35 2.83	80 47.40	625.0	2	1715.35	37.24	15.92	14.88
953	35 14.08	80 47.42	701.0	2	1720.93	34.03	10.11	8.94
1004	35 0.49	80 47.45	642.0	4	1701.20	28.00	6.10	5.03
163	35 11.66	80 47.45	742.0	2	1716.49	36.88	11.56	10.32
B213	35 4.90	80 47.49	616.0	3	1717.25	35.37	14.35	13.33
B1014	35 4.10	80 47.66	652.0	5	1713.85	36.48	14.23	13.15
147	35 15.88	80 47.70	752.0	2	1717.74	33.07	7.41	6.16
1030	35 6.61	80 47.76	621.0	2	1724.29	40.45	19.26	18.23
949	35 14.98	80 47.79	738.0	2	1718.81	34.10	8.92	7.69
162	35 10.57	80 47.83	729.0	2	1716.01	36.72	11.84	10.63
213	35 5.50	80 47.86	667.0	2	1717.34	39.40	16.64	15.53
161	35 9.59	80 48.01	654.0	1	1719.41	34.45	12.14	11.05
168	35 13.55	80 48.06	722.0	2	1718.29	34.11	9.47	8.27
955	35 12.76	80 48.08	653.0	3	1722.63	33.08	10.80	9.72
1016	35 3.64	80 48.16	654.0	3	1713.74	37.21	14.90	13.81
976	35 8.31	80 48.19	690.0	2	1713.87	34.11	10.56	9.42
967	35 11.77	80 48.25	657.0	4	1722.18	34.41	11.99	10.90
1003	35 0.24	80 48.28	635.0	2	1702.63	29.14	7.47	6.41
1017	35 1.97	80 48.36	603.0	3	1715.96	37.00	16.43	15.43
954	35 13.96	80 48.49	767.0	3	1715.86	35.33	9.16	7.89
148	35 15.15	80 48.49	706.0	2	1721.07	33.12	9.03	7.85
969	35 11.24	80 48.60	641.0	5	1721.94	33.42	11.54	10.48
568	35 3.21	80 48.82	676.0	1	1709.60	35.75	12.68	11.56
1032	35 7.16	80 47.88	570.0	5	1726.06	36.65	17.20	16.25
989	35 7.37	80 49.05	659.0	2	1719.35	38.01	15.52	14.42
960	35 14.82	80 49.09	705.0	2	1722.54	34.95	10.90	9.73
569	35 1.81	80 49.23	657.0	2	1709.01	35.36	12.94	11.85
461	35 11.83	80 49.25	686.0	2	1719.05	33.93	10.52	9.38
149	35 13.66	80 49.28	720.0	2	1718.19	33.66	9.10	7.90
A212	35 4.40	80 49.34	551.0	3	1721.87	34.58	15.78	14.86
1026	35 3.91	80 49.36	641.0	2	1712.24	34.11	12.24	11.18
212	35 5.04	80 49.37	607.0	2	1721.59	38.66	17.95	16.94

STA.	LAT	LONG	ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
462	35 10.32	80 49.40	659.0	2	1721.50	35.97	13.49	12.39
1018	35 2.75	80 49.47	696.0	2	1704.18	32.86	9.11	7.96
1002	35 0.44	80 49.49	635.0	2	1702.56	28.78	7.12	6.06
966	35 12.64	80 49.49	727.0	3	1717.04	34.62	9.81	8.60
978	35 9.29	80 49.50	697.0	2	1718.09	37.60	13.82	12.66
990	35 6.43	80 49.61	622.0	2	1725.90	42.41	21.19	20.15
991	35 5.75	80 49.63	570.0	5	1727.97	40.55	21.10	20.15
977	35 8.01	80 49.67	650.0	3	1717.43	34.34	12.16	11.08
965	35 11.34	80 49.84	695.0	3	1717.92	34.34	10.62	9.47
988	35 7.19	80 49.87	611.0	2	1724.20	38.60	17.75	16.73
1001	35 1.16	80 49.95	647.0	2	1703.45	29.78	7.70	6.63
1028	35 2.17	80 50.10	690.0	5	1700.72	29.66	6.12	4.97
957	35 13.15	80 50.19	682.0	3	1720.91	33.53	10.26	9.13
959	35 14.66	80 50.20	734.0	3	1720.19	35.56	10.51	9.29
37	35 16.41	80 50.21	760.0	1	1719.83	35.16	9.23	7.97
992	35 5.91	80 50.31	603.0	2	1728.68	44.14	23.57	22.57
160	35 7.90	80 50.50	697.0	1	1714.68	36.17	12.38	11.23
964	35 10.74	80 50.50	646.0	3	1719.98	32.64	10.60	9.52
1027	35 4.00	80 50.56	584.0	3	1719.22	35.60	15.67	14.70
460	35 12.03	80 50.59	690.0	2	1719.89	34.85	11.31	10.16
987	35 7.17	80 50.69	642.0	2	1723.79	41.13	19.23	18.16
999	35 0.28	80 50.71	648.0	5	1694.78	22.45	0.34	-0.74
211	35 5.26	80 50.72	609.0	2	1726.19	43.14	22.36	21.35
979	35 8.64	80 50.74	679.0	2	1716.40	35.14	11.98	10.85
1019	35 2.50	80 50.85	665.0	1	1701.89	28.02	5.33	4.22
981	35 9.54	80 50.93	600.0	5	1723.71	33.74	13.27	12.27
208	35 1.25	80 50.98	685.0	2	1696.21	25.99	2.62	1.48
1000	35 0.89	80 51.10	670.0	1	1695.72	24.59	1.73	0.62
963	35 11.45	80 51.20	696.0	3	1719.63	35.98	12.23	11.08
38	35 16.31	80 51.30	769.0	5	1719.19	35.51	9.27	7.99
37	35 16.41	80 51.30	760.0	1	1719.89	35.22	9.29	8.02
A985	35 14.55	80 51.39	750.0	5	1718.94	35.98	10.38	9.14
982	35 10.33	80 51.44	644.0	2	1720.37	33.42	11.44	10.37
994	35 6.62	80 51.48	626.0	2	1728.23	44.85	23.49	22.45
150	35 12.73	80 51.54	740.0	1	1716.89	35.56	10.31	9.08

STA.	LAT	LONG	ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
993	35 5.79	80 51.59	607.0	2	1728.83	44.84	24.12	23.12
207	35 2.37	80 51.71	651.0	1	1700.98	25.98	3.76	2.68
980	35 7.95	80 51.76	607.0	3	1721.96	34.90	14.19	13.18
209	35 0.05	80 51.78	654.0	2	1692.74	21.30	-1.02	-2.10
159	35 8.87	80 51.82	638.0	2	1720.24	34.79	13.02	11.96
961	35 13.72	80 51.84	648.0	2	1723.26	31.88	9.77	8.69
958	35 14.87	80 51.86	690.0	2	1723.50	34.44	10.89	9.75
998	35 0.84	80 51.96	662.0	2	1695.61	23.80	1.21	0.11
997	35 1.49	80 52.00	620.0	2	1700.95	24.27	3.11	2.08
984	35 11.11	80 52.09	705.0	3	1719.66	37.34	13.29	12.12
995	35 3.91	80 52.11	521.0	2	1722.64	33.22	15.44	14.58
151	35 11.96	80 52.16	739.0	2	1716.93	36.60	11.39	10.16
210	35 5.34	80 52.25	602.0	2	1724.90	41.08	20.54	19.54
983	35 10.47	80 52.31	695.0	2	1718.25	35.90	12.18	11.03
986	35 9.80	80 52.35	698.0	2	1719.19	38.07	14.25	13.10
206	35 3.32	80 52.39	615.0	1	1707.96	28.22	7.23	6.21
158	35 8.10	80 52.58	663.0	1	1720.99	38.99	16.37	15.27
996	35 1.95	80 52.59	654.0	1	1698.50	24.37	2.05	0.97
205	35 3.78	80 52.62	536.0	1	1717.40	29.58	11.29	10.40
1039	35 0.18	80 52.68	604.0	2	1694.43	18.10	-2.51	-3.51
157	35 9.18	80 52.68	692.0	2	1718.23	37.43	13.81	12.66
1102	35 14.52	80 52.69	752.0	2	1717.99	35.25	9.59	8.34
203	35 7.30	80 52.83	683.0	1	1719.42	40.44	17.13	16.00
1094	35 12.00	80 53.08	690.0	2	1719.64	34.65	11.10	9.96
962	35 13.44	80 53.08	742.0	2	1716.17	34.03	8.71	7.47
1035	35 2.25	80 53.11	611.0	2	1701.19	22.59	1.74	0.73
204	35 4.75	80 53.12	559.0	1	1721.67	34.64	15.57	14.64
202	35 5.69	80 53.16	587.0	1	1726.58	40.85	20.82	19.84
1037	35 1.40	80 53.30	616.0	2	1700.38	23.46	2.44	1.41
152	35 10.80	80 53.38	721.0	1	1717.93	37.56	12.95	11.76
A152	35 10.80	80 53.38	721.0	1	1717.77	37.40	12.80	11.60
156	35 7.86	80 53.50	686.0	2	1718.66	39.17	15.76	14.62
1059	35 3.61	80 53.60	643.0	2	1705.59	28.08	6.13	5.07
1034	35 2.86	80 53.62	627.0	2	1701.81	23.85	2.45	1.41

STA.	LAT		LONG		ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
1038	35	0.74	80	53.63	509.0	3	1702.94	16.88	-0.48	-1.33
1020	35	8.62	80	53.68	695.0	2	1718.94	39.21	15.50	14.34
1022	35	10.32	80	53.74	681.0	2	1719.63	36.18	12.94	11.81
1036	35	1.92	80	53.80	530.0	5	1703.96	18.21	0.12	-0.76
1033	35	4.73	80	53.81	587.0	3	1720.00	35.63	15.60	14.62
1103	35	14.29	80	53.84	780.0	5	1715.73	35.95	9.34	8.04
1021	35	9.41	80	53.92	700.0	5	1718.54	38.16	14.27	13.11
201	35	5.40	80	53.94	545.0	1	1727.14	37.87	19.27	18.37
1065	35	6.31	80	54.00	564.0	3	1730.23	41.45	22.21	21.27
1101	35	13.49	80	54.14	765.0	2	1714.49	34.44	8.33	7.06
1040	35	0.34	80	54.18	514.0	1	1699.59	14.57	-2.97	-3.82
1060	35	5.44	80	54.25	550.0	5	1726.93	38.08	19.31	18.40
1024	35	11.20	80	54.27	688.0	2	1718.95	34.91	11.43	10.29
1025	35	11.82	80	54.27	612.0	2	1723.15	31.07	10.19	9.17
1096	35	12.51	80	54.28	696.0	2	1718.54	33.39	9.64	8.49
1023	35	10.58	80	54.57	670.0	2	1720.12	35.26	12.40	11.28
1064	35	6.92	80	54.63	606.0	2	1728.92	43.24	22.56	21.55
155	35	8.37	80	54.68	578.0	2	1731.45	41.07	21.35	20.39
153	35	9.88	80	54.76	593.0	1	1726.30	35.19	14.96	13.97
1104	35	14.83	80	54.80	777.0	2	1714.83	34.00	7.49	6.20
1044	35	2.42	80	54.92	634.0	2	1699.52	22.84	1.21	0.16
1061	35	4.49	80	54.94	628.0	2	1714.62	34.45	13.02	11.98
1063	35	6.22	80	54.98	620.0	2	1725.98	42.60	21.44	20.41
1043	35	1.43	80	55.06	522.0	2	1703.96	18.14	0.33	-0.53
1099	35	13.24	80	55.06	710.0	5	1716.94	32.07	7.84	6.66
200	35	5.37	80	55.10	621.0	1	1719.23	37.15	15.96	14.93
1046	35	3.57	80	55.28	601.0	2	1712.64	31.23	10.72	9.72
A94	35	15.81	80	55.28	744.0	2	1715.18	29.86	4.47	3.24
1041	35	0.47	80	55.30	644.0	1	1694.14	21.16	-0.81	-1.88
1100	35	13.75	80	55.36	746.0	2	1715.11	32.90	7.44	6.20
154	35	8.82	80	55.56	589.0	2	1733.07	43.09	22.99	22.01
1134	35	10.35	80	55.59	680.0	5	1719.75	36.16	12.96	11.83
1098	35	12.51	80	55.62	670.0	5	1718.81	31.21	8.35	7.24
1045	35	2.88	80	55.63	627.0	2	1704.07	26.08	4.69	3.64
1105	35	14.66	80	55.63	774.0	2	1713.67	32.81	6.39	5.11

STA.	LAT	LONG	ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
A1099	35 13.35	80 55.73	700.0	5	1716.87	30.90	7.02	5.85
1133	35 11.38	80 55.75	702.0	2	1715.30	32.32	8.37	7.20
1042	35 0.13	80 55.76	658.0	2	1692.72	21.54	-0.91	-2.00
1047	35 2.15	80 55.82	543.0	3	1703.59	18.74	0.21	-0.70
1128	35 9.77	80 55.82	607.0	1	1728.28	38.65	17.93	16.92
1067	35 7.70	80 55.86	636.0	3	1730.72	46.75	25.05	23.99
B1098	35 12.82	80 55.89	710.0	5	1715.03	30.75	6.52	5.35
1062	35 5.47	80 55.90	640.0	1	1719.33	38.90	17.06	15.99
A1098	35 12.52	80 55.95	710.0	5	1715.72	31.87	7.64	6.46
1066	35 6.66	80 56.10	645.0	2	1725.81	44.16	22.15	21.08
1154	35 4.38	80 56.13	645.0	2	1710.83	32.41	10.40	9.32
95	35 16.49	80 56.21	782.0	2	1711.39	28.68	2.00	0.70
1058	35 3.21	80 56.30	600.0	5	1705.16	24.16	3.69	2.69
69	35 14.37	80 56.37	782.0	1	1711.39	31.69	5.01	3.71
69	35 14.37	80 56.37	782.0	1	1711.35	31.65	4.96	3.66
1048	35 1.35	80 56.40	622.0	2	1695.76	19.46	-1.76	-2.79
195	35 7.79	80 56.49	649.0	1	1729.35	46.47	24.33	23.25
1129	35 10.23	80 56.61	705.0	1	1717.91	36.84	12.79	11.62
199	35 6.06	80 56.62	637.0	2	1721.93	40.37	18.64	17.58
1097	35 12.00	80 56.64	692.0	3	1714.25	29.44	5.83	4.68
1155	35 2.40	80 56.66	616.0	2	1698.60	20.26	-0.76	-1.78
194	35 7.41	80 56.71	633.0	2	1729.75	45.91	24.31	23.26
A1097	35 12.30	80 56.73	700.0	5	1714.72	30.25	6.36	5.20
70	35 13.69	80 56.75	739.0	2	1710.72	27.94	2.73	1.50
1130	35 10.78	80 56.99	700.0	5	1714.83	32.51	8.62	7.46
1126	35 8.64	80 57.02	645.0	3	1729.78	45.32	23.31	22.24
1106	35 14.76	80 57.17	750.0	5	1712.00	28.74	3.14	1.90
198	35 5.20	80 57.38	589.0	2	1720.98	36.13	16.03	15.05
1125	35 9.15	80 57.22	673.0	2	1725.63	43.09	20.12	19.00
1127	35 8.25	80 57.32	623.0	3	1732.17	46.19	24.94	23.90
1057	35 2.60	80 57.41	630.0	5	1697.20	19.89	-1.61	-2.65
1049	35 1.18	80 57.45	647.0	2	1693.12	19.42	-2.65	-3.73
1076	35 4.57	80 57.47	616.0	2	1712.26	30.84	9.82	8.80
2A71	35 12.89	80 57.47	750.0	5	1709.37	28.76	3.17	1.92
1068	35 5.90	80 57.56	592.0	2	1724.99	39.43	19.23	18.24

STA.	LAT	LONG	ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
1117	35 10.28	80 57.70	726.0	3	1715.00	35.84	11.07	9.86
459	35 11.37	80 57.72	733.0	1	1710.16	30.11	5.09	3.88
1132	35 12.18	80 57.73	746.0	1	1708.70	28.72	3.27	2.03
193	35 6.91	80 57.74	626.0	2	1727.95	44.15	22.79	21.75
1124	35 9.16	80 57.75	627.0	5	1728.82	41.93	20.54	19.50
71	35 13.43	80 57.80	760.0	1	1708.42	27.98	2.05	0.79
1075	35 3.67	80 57.84	658.0	2	1696.97	20.78	-1.67	-2.77
A71	35 13.56	80 58.08	732.0	2	1709.92	26.67	1.69	0.47
1107	35 14.37	80 58.15	642.0	3	1717.53	24.66	2.75	1.69
1123	35 9.25	80 58.22	660.0	1	1726.47	42.56	20.03	18.94
1118	35 9.68	80 58.25	678.0	2	1722.53	39.71	16.57	15.44
1069	35 5.94	80 58.26	587.0	2	1724.98	38.89	18.86	17.89
C1110	35 13.14	80 58.26	629.0	3	1708.93	16.59	-4.88	-5.92
1074	35 2.86	80 58.27	630.0	2	1695.33	17.66	-3.84	-4.89
1131	35 11.36	80 58.36	705.0	3	1710.06	27.39	3.33	2.16
1073	35 3.78	80 58.45	687.0	2	1694.36	20.74	-2.70	-3.84
1056	35 2.13	80 58.53	680.0	5	1690.62	18.68	-4.52	-5.65
1095	35 12.76	80 53.54	696.0	4	1719.38	33.87	10.12	8.96
A1122	35 8.34	80 58.59	640.0	3	1728.43	43.93	22.09	21.03
1110	35 13.15	80 58.59	629.0	2	1708.03	15.66	-5.80	-6.84
1110	35 13.15	80 58.59	629.0	2	1708.07	15.71	-5.75	-6.80
197	35 5.16	80 58.60	660.0	1	1711.55	33.44	10.92	9.82
1112	35 11.97	80 58.63	711.0	2	1709.23	26.26	1.99	0.81
A1110	35 12.98	80 58.64	589.0	3	1709.95	14.07	-6.03	-7.01
1116	35 10.36	80 58.67	701.0	3	1713.96	32.33	8.41	7.25
72	35 13.79	80 58.67	631.0	2	1715.74	22.66	1.13	0.08
192	35 6.47	80 58.74	619.0	2	1724.88	41.05	19.93	18.90
1050	35 0.17	80 58.81	646.0	2	1685.04	12.67	-9.37	-10.44
1135	35 7.54	80 58.84	654.0	0	1726.28	44.23	21.91	20.82
1070	35 7.07	80 58.85	645.0	3	1725.89	44.03	22.02	20.95
1051	35 0.96	80 58.87	706.0	1	1683.09	15.26	-8.84	-10.01
B1110	35 13.11	80 59.00	701.0	3	1708.64	23.11	-0.81	-1.97
1119	35 9.40	80 59.03	645.0	2	1723.88	38.34	16.33	15.26
1072	35 4.49	80 59.04	695.0	2	1698.48	24.60	0.89	-0.27

STA.	LAT	LONG	ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
A1108	35 14.55	80 59.05	705.0	3	1715.25	28.05	4.00	2.83
1108	35 14.94	80 59.08	707.0	3	1712.48	24.91	0.79	-0.39
A1111	35 12.83	80 59.28	653.0	3	1711.50	21.85	-0.43	-1.52
1055	35 2.76	80 59.36	676.0	2	1690.43	17.22	-5.85	-6.97
191	35 6.12	80 59.40	633.0	2	1718.45	36.44	14.84	13.79
1120	35 9.03	80 59.40	603.0	2	1726.36	37.40	16.82	15.82
1114	35 10.90	80 59.49	688.0	3	1709.68	26.07	2.59	1.45
1113	35 12.07	80 59.54	710.0	2	1706.31	23.10	-1.12	-2.30
196	35 5.17	80 59.55	698.0	1	1703.88	29.32	5.51	4.35
A196	35 5.17	80 59.55	697.0	1	1704.20	29.55	5.77	4.61
1052	35 1.16	80 59.65	523.0	1	1694.32	8.99	-8.86	-9.73
1111	35 12.85	80 59.68	642.0	3	1711.04	20.32	-1.58	-2.65
73	35 14.27	80 59.82	710.0	2	1710.16	23.83	-0.40	-1.58
A73	35 13.97	80 59.78	632.0	1	1714.01	20.77	-0.80	-1.85
73	35 14.27	80 59.82	710.0	2	1710.17	23.84	-0.38	-1.56
1115	35 10.34	80 59.83	612.0	3	1715.95	25.98	5.10	4.08
1071	35 7.29	80 59.99	654.0	2	1719.94	38.24	15.93	14.84
1054	35 2.19	81 0.16	653.0	1	1689.72	15.15	-7.13	-8.21
1121	35 9.37	81 0.16	611.0	2	1719.95	31.26	10.41	9.40
1109	35 13.52	81 0.16	695.0	2	1707.51	20.83	-2.88	-4.04
74	35 14.60	81 0.16	637.0	2	1715.43	21.77	0.03	-1.03
1077	35 5.01	81 0.26	725.0	5	1696.80	25.02	0.28	-0.93
1088	35 3.31	81 0.36	695.0	2	1689.60	17.40	-6.32	-7.47
190	35 5.63	81 0.36	706.0	2	1702.87	28.42	4.33	3.16
1053	35 1.39	81 0.37	535.0	2	1695.05	10.52	-7.74	-8.62
1092	35 6.54	81 0.38	652.0	3	1713.30	32.48	10.23	9.15
1087	35 4.14	81 0.40	721.0	2	1689.58	18.65	-5.95	-7.15
1204	35 12.02	81 0.60	604.0	2	1710.78	17.67	-2.94	-3.95
1137	35 8.17	81 0.67	644.0	2	1718.26	34.37	12.40	11.33
1140	35 8.74	81 0.83	644.0	2	1716.36	31.67	9.69	8.62
75	35 14.78	81 0.84	586.0	2	1717.40	18.68	-1.32	-2.29
1136	35 7.57	81 0.94	683.0	1	1711.84	32.48	9.17	8.04
1157	35 0.19	81 1.06	629.0	2	1687.75	13.76	-7.71	-8.75
1203	35 11.23	81 1.14	670.0	5	1705.48	19.70	-3.16	-4.28
1078	35 5.60	81 1.24	700.0	4	1695.43	20.46	-3.43	-4.59

STA.	LAT		LONG		ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
1202	35	10.20	81	1.24	681.0	2	1705.43	22.14	-1.10	-2.23
1084	35	4.34	81	1.31	727.0	2	1687.77	17.12	-7.69	-8.89
1090	35	2.13	81	1.33	713.0	3	1686.51	17.68	-6.65	-7.84
1093	35	6.67	81	1.43	655.0	2	1704.67	23.95	1.60	0.51
1091	35	1.30	81	1.48	566.0	1	1693.90	12.41	-6.91	-7.85
1085	35	3.52	81	1.50	661.0	2	1690.56	14.86	-7.69	-8.79
1205	35	12.26	81	1.60	710.0	5	1702.34	18.86	-5.37	-6.55
1208	35	13.57	81	1.66	687.0	2	1705.45	17.95	-5.50	-6.64
76	35	15.10	81	1.70	633.0	2	1713.32	18.57	-3.03	-4.09
1079	35	4.96	81	1.80	614.0	4	1694.61	12.45	-8.50	-9.52
1138	35	7.72	81	1.92	629.0	2	1708.00	23.34	1.88	0.83
1089	35	2.29	81	2.01	651.0	2	1690.69	15.79	-6.42	-7.50
1201	35	10.10	81	2.25	565.0	4	1709.76	15.70	-3.58	-4.51
189	35	5.81	81	2.29	642.0	2	1693.83	13.10	-8.81	-9.87
1210	35	14.02	81	1.96	683.0	2	1705.91	17.40	-5.91	-7.04
1198	35	11.01	81	2.38	603.0	2	1706.87	15.10	-5.47	-6.48
1086	35	3.18	81	2.41	639.0	3	1691.23	13.94	-7.86	-8.92
1206	35	12.27	81	2.49	661.0	3	1703.05	14.95	-7.61	-8.71
1158	35	0.90	81	2.50	643.0	2	1686.86	13.19	-8.76	-9.82
1080	35	4.62	81	2.55	692.0	2	1688.61	14.27	-9.34	-10.49
77	35	15.80	81	2.57	734.0	2	1704.36	18.11	-6.93	-8.15
1159	35	1.53	81	2.63	565.0	1	1693.15	11.24	-8.04	-8.98
1083	35	4.00	81	2.93	654.0	2	1690.93	13.89	-8.42	-9.51
1141	35	6.60	81	2.93	638.0	3	1697.37	15.15	-6.62	-7.68
458	35	9.65	81	2.93	658.0	2	1701.80	17.14	-5.32	-6.41
1197	35	11.52	81	2.94	600.0	5	1705.01	12.24	-8.23	-9.23
1209	35	13.99	81	2.97	682.0	2	1703.67	15.11	-8.17	-9.30
1207	35	13.16	81	3.10	707.0	3	1700.58	15.54	-8.59	-9.76
1081	35	4.55	81	3.13	566.0	1	1696.04	9.95	-9.36	-10.30
1082	35	5.16	81	3.14	566.0	1	1696.15	9.20	-10.12	-11.06
1169	35	3.15	81	3.24	565.0	1	1696.30	12.10	-7.18	-8.12
1199	35	10.80	81	3.33	685.0	2	1699.17	15.41	-7.96	-9.10
1170	35	2.21	81	3.38	615.0	3	1691.41	13.24	-7.75	-8.77
1175	35	8.56	81	3.42	575.0	2	1703.92	12.99	-6.63	-7.58
1190	35	14.73	81	3.46	630.0	5	1706.30	11.79	-9.71	-10.76

STA.	LAT		LONG		ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
1160	35	0.67	81	3.49	633.0	2	1685.97	11.68	-9.92	-10.97
1143	35	5.74	81	3.57	608.0	3	1693.84	10.02	-10.73	-11.74
169	35	15.17	81	3.72	681.0	1	1702.43	12.10	-11.14	-12.27
1183	35	12.55	81	3.75	576.0	2	1704.84	8.34	-11.31	-12.27
188	35	6.91	81	3.86	680.0	1	1694.67	15.96	-7.24	-8.37
1142	35	6.28	81	3.88	664.0	3	1693.90	14.58	-8.08	-9.18
1196	35	11.48	81	3.90	691.0	2	1696.24	12.09	-11.49	-12.64
281	35	7.33	81	5.98	663.0	2	1689.69	8.78	-13.85	-14.95
1174	35	8.04	81	4.16	650.0	5	1696.43	13.29	-8.89	-9.97
1166	35	1.68	81	4.17	602.0	2	1690.82	12.18	-8.36	-9.36
1171	35	2.64	81	4.18	565.0	1	1692.70	9.22	-10.06	-11.00
1200	35	9.67	81	4.21	602.0	5	1698.74	8.78	-11.76	-12.76
1172	35	4.09	81	4.41	565.0	1	1694.80	9.27	-10.01	-10.95
1153	35	4.95	81	4.43	642.0	3	1690.66	11.15	-10.76	-11.83
1194	35	13.64	81	4.48	586.0	4	1704.50	7.40	-12.60	-13.57
1152	35	5.58	81	4.58	634.0	4	1693.98	12.82	-8.81	-9.86
1193	35	14.43	81	4.63	590.0	5	1703.18	5.33	-14.80	-15.78
1161	35	0.51	81	4.74	639.0	2	1684.23	10.73	-11.08	-12.14
1195	35	12.77	81	4.93	733.0	3	1692.13	10.09	-14.92	-16.14
1144	35	6.50	81	4.99	566.0	2	1699.33	10.48	-8.83	-9.77
184	35	7.12	81	5.02	648.0	2	1693.58	11.56	-10.55	-11.63
1162	35	1.60	81	5.14	565.0	2	1691.40	9.39	-9.89	-10.83
1191	35	14.84	81	5.14	683.0	5	1698.70	9.02	-14.28	-15.42
1184	35	12.25	81	5.17	692.0	4	1692.77	7.61	-16.00	-17.15
1182	35	10.22	81	5.19	678.0	2	1692.11	8.52	-14.62	-15.74
170	35	15.52	81	5.22	686.0	2	1699.20	8.83	-14.57	-15.71
1176	35	8.10	81	5.23	660.0	5	1692.39	10.10	-12.42	-13.51
1173	35	4.79	81	5.26	670.0	5	1689.18	12.53	-10.33	-11.44
457	35	11.24	81	5.36	668.0	2	1694.21	8.22	-14.57	-15.68
1145	35	6.62	81	5.38	566.0	2	1697.36	8.33	-10.98	-11.92
1165	35	2.20	81	5.40	623.0	2	1688.85	11.45	-9.81	-10.84
284	35	4.10	81	5.44	690.0	2	1687.10	13.31	-10.24	-11.38
183	35	9.10	81	5.48	708.0	2	1689.45	10.26	-13.90	-15.07
282	35	5.96	81	5.66	659.0	2	1690.40	11.06	-11.43	-12.52

STA.	LAT	LONG	ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
1168	35 3.05	81 5.91	565.0	1	1693.88	9.82	-9.46	-10.40
1177	35 8.42	81 5.92	680.0	5	1689.81	8.95	-14.25	-15.38
1181	35 11.15	81 6.02	724.0	2	1687.88	7.29	-17.41	-18.62
1192	35 14.23	81 6.03	736.0	1	1691.49	7.66	-17.46	-18.68
1186	35 13.38	81 6.06	757.0	2	1686.72	6.07	-19.76	-21.01
285	35 0.49	81 6.14	696.0	1	1684.24	16.12	-7.63	-8.78
3511	35 16.0	81 6.2					-20.0	
1164	35 1.50	81 6.22	637.0	2	1689.72	14.63	-7.11	-8.16
182	35 9.73	81 6.23	712.0	2	1687.50	7.80	-16.50	-17.68
283	35 4.91	81 6.33	730.0	1	1681.94	10.76	-14.15	-15.36
1146	35 5.45	81 6.40	628.0	2	1688.68	7.15	-14.28	-15.33
1185	35 12.32	81 6.69	700.0	5	1687.79	3.29	-20.60	-21.76
1151	35 4.31	81 6.78	702.0	2	1681.87	8.91	-15.05	-16.21
1187	35 13.88	81 6.83	776.0	2	1686.52	6.95	-19.53	-20.82
181	35 10.64	81 6.85	727.0	2	1685.78	6.20	-18.61	-19.82
1163	35 0.18	81 6.97	716.0	3	1680.39	14.60	-9.83	-11.02
1180	35 9.62	81 6.98	728.0	2	1683.61	5.57	-19.27	-20.48
280	35 7.18	81 7.10	633.0	1	1687.63	4.11	-17.49	-18.54
1188	35 13.04	81 7.09	690.0	5	1689.02	2.56	-20.99	-22.13
1178	35 8.82	81 7.10	711.0	2	1683.38	4.87	-19.39	-20.57
1148	35 6.14	81 7.20	721.0	2	1680.15	6.38	-18.22	-19.42
1167	35 2.31	81 7.28	678.0	3	1683.20	10.81	-12.32	-13.45
1179	35 7.91	81 7.28	684.0	2	1683.26	3.51	-19.83	-20.97
286	35 0.93	81 7.35	608.0	3	1686.43	9.42	-11.33	-12.34
1150	35 3.60	81 7.39	591.0	2	1685.52	3.13	-17.04	-18.02
1189	35 14.52	81 7.41	770.0	2	1679.95	-1.10	-27.37	-28.65
1149	35 4.75	81 7.44	705.0	2	1679.44	6.14	-17.92	-19.09
1147	35 5.26	81 7.48	722.0	2	1679.01	6.59	-18.05	-19.25
279	35 7.17	81 7.30	632.0	3	1687.64	4.04	-17.52	-18.57
180	35 11.46	81 7.89	777.0	1	1676.98	0.94	-25.57	-26.87
178	35 12.85	81 8.00	746.0	2	1683.02	2.09	-23.37	-24.61
179	35 12.35	81 8.02	748.0	2	1680.14	0.11	-25.41	-26.66
287	35 1.87	81 8.06	711.0	3	1678.87	10.22	-14.05	-15.23
278	35 6.27	81 8.08	679.0	3	1677.97	0.07	-23.10	-24.22

STA.	LAT		LONG		ELEV(F)	E	OBS G	FAA	BA 2.67	BA 2.80
187	35	13.59	81	8.19	736.0	2	1683.06	0.14	-24.98	-26.20
293	35	7.57	81	8.24	679.0	2	1677.65	-2.09	-25.26	-26.39
881	35	7.73	80	39.62	743.0	2	1704.16	30.25	4.90	3.67
1156	35	0.45	80	57.75	618.0	2	1692.84	17.44	-3.65	-4.67
186	35	14.69	81	8.33	795.0	2	1678.23	-0.71	-27.83	-29.16
	35	5.4	81	8.4	716				-22.1	
	35	3.2	80	38.30	658				2.7	
	35	3.4	80	38.60	658				3.5	
	35	13.79	80	58.10	680.1				2.0	
	35	14.2	80	49.80	708.0				11.1	
	35	14.10	80	51.20	727				10.3	
	35	8.90	80	44.8	588.0				9.3	
	35	7.00	80	43.20	729.0				5.8	
	35	9.50	80	33.90	178.6				4.8	
	35	14.90	80	31.30	164.0				6.2	
	35	14.7	81	2.40	680.1				-6.2	

APPENDIX C

Gravity Base Stations

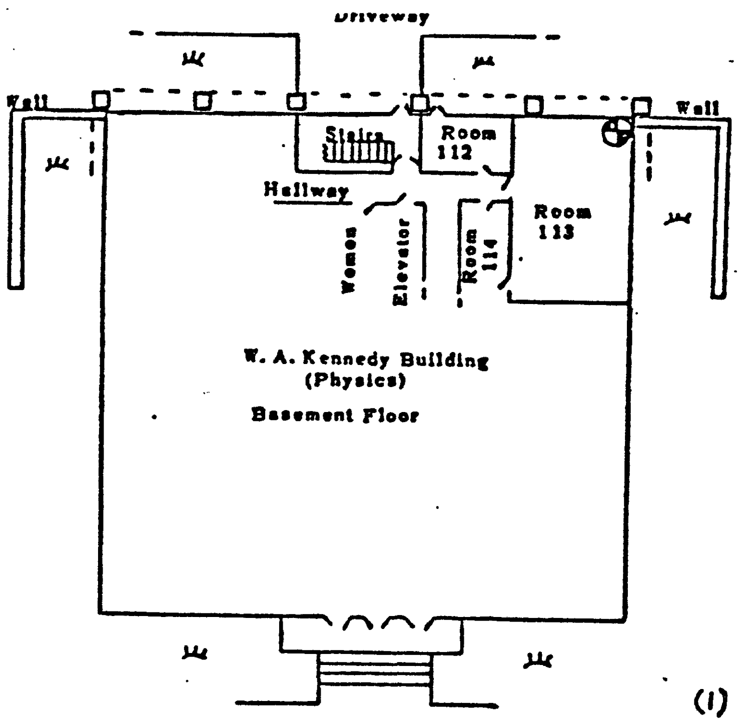
GRAVITY BASE STATION

LATITUDE 35° 12.00' N (1)	STATION DESIGNATION CHARLOTTE
LONGITUDE 80° 56.00' W (1)	
ELEVATION 230.00 METERS (1)	COUNTRY/STATE USA/North Carolina
REFERENCE CODE NUMBERS	ADOPTED GRAVITY VALUE
ACIC 2096-1 IGC 11750A	g= 979 741.79 mgals
ESTIMATED ACCURACY	DATE MONTH/YEAR
± 0.1 mgals	July/1967

DESCRIPTION AND/OR SKETCH

The station is about eight miles northeast of Charlotte, on North Carolina Highway 49, at the University of North Carolina at Charlotte (formerly Charlotte College), in the W. A. Kennedy Building (Physics Building, built in 1962), in the basement floor, northeast corner, in Room 113 (a Physics Lab), in the northeast corner, on the tile floor.

Station is monumented with a USAF Gravity Disk. (1)



(1)

REFERENCE SOURCE

(1) 02733

Secondary Base Stations

Station	Latitute Deg. Min.	Longitude Deg. Min.	Elevation (F) (M)	Gravity Value Mgls.	Location
HOLIN	35° 16.86'	80° 47.52'	789 240	979718.26	Holiday Inn I85 - Bottle cap nailed at end of yellow line between tar and concrete at the north edge of parking lot opposite door 233.
STVR37	35° 16.41'	80° 56.37'	760 232	979719.85	NW quadrant of US 21 (Statesville Road) and I85 - National Geodetic Survey, Quadrangle 35 0803, Line 107, BM "Howard" page 34
GULF69	35° 14.37'	80° 56.37'	782 238	979711.45	N.C. Triangulation Survey Station - 98-B "GULF" 69.3' N of Gulf sign post. National Geodetic Survey Quadrangle 35 08 03, Line 107, BM "GULF" page 32
MON770	34° 59.25'	80° 31.98	584 178	979708.25	Bottle cap in 2nd concrete expansion joint. S. Cor. Holiday Inn between electric trans-former and garbage container.
DAY985	35° 10.77'	80° 30.56'	735 224	979716.65	Bottle cap nailed in 2nd expansion joint in sidewalk and curb, north of driveway at the rear of Days Inn Restaurant.

APPENDIX D

Sample locations and physical property data

listed by quadrangle

LAT	-	Latitude
LONG	-	Longitude
DEN	-	Density g/cc
MAG.SUS.	-	Magnetic susceptibility c.g.s.
Ji	-	Induced magnetism c.g.s.
Jr	-	Remanent magnetism c.g.s.
Q	-	Konigsberger ratio
Rx	-	Rock code

Rock Code (Rx)

Gabbro (gb)	1
Hornblende gabbro (mgb)	2
Diorite (di)	3
Tonalite (mgdi)	4
Granodiorite (gdi)(mgdi)	5
Monzonite (Pzmz)	6
Syenite (Pzsy)	7
Granite (Pzgr)	8
Aplite	9
Amphybolite	10
Metavolcanic Felsic (mvf)	11
Metavolcanic Mafic (mvm)	12
Mudstone (Cc)	13
Quartz schist (qs)	14
Other schist (mqdi)	15
Quartz vein	16
Aplite/gold	17
Gneiss mafic (mqdi etc)	18
Gneiss felsic (mqdi etc)	19
Slate (Cp)	20
Basalt-diabase dikes	21

SAMPLE	LAT.	LONG.	DEN.	MAG.SUS.	JI	Jr	Q	RX
B815	35 7.50	80 36.23	2.63	0.320E-04	0.176E-04			11
B815A	35 6.84	80 36.08	0.00	0.000E+00	0.000E+00			16
B815B	35 7.50	80 36.23	2.62	0.000E+00	0.000E+00			11
B815C	35 7.50	80 36.23	2.73	0.000E+00	0.000E+00			11
B817	35 6.60	80 34.55	2.63	0.000E+00	0.000E+00			20
B485	35 1.98	80 36.44	2.75	0.320E-04	0.176E-04			13
B788	35 4.60	80 30.34	2.73	0.330E-04	0.181E-04			13
B490	35 1.85	80 32.30	2.61	0.000E+00	0.000E+00			13
BE811	35 5.39	80 36.40	2.84	0.520E-04	0.286E-04			10
BE1178	35 8.10	81 6.55	2.94	0.920E-04	0.506E-04			2
BE1182	35 9.90	81 5.28	2.70	0.125E-02	0.689E-03	0.252E-03	0.37	4
BE1194	35 13.75	81 4.96	2.68	0.000E+00	0.000E+00			14
CE151	35 11.95	80 52.14	2.68	0.267E-03	0.147E-03			11
CE166	35 13.34	80 46.98	2.92	0.108E-02	0.595E-03	0.589E-03	0.99	10
CE168	35 13.44	80 47.56	2.67	0.100E-04	0.550E-05			11
CE462B	35 10.53	80 49.66	2.63	0.241E-03	0.133E-03			8
CE462B1	35 10.11	80 49.75	3.03	0.379E-02	0.209E-02	0.262E-03	0.13	2
CE462B2	35 10.11	80 49.75	2.75	0.189E-03	0.104E-03			10
CE462-AD1	35 10.34	80 50.18	2.68	0.270E-04	0.148E-04			8
CE462-AD2	35 10.34	80 50.18	2.64	0.722E-03	0.397E-03			8
CE951	35 13.97	80 46.46	2.90	0.500E-04	0.275E-04			3
CE982	35 10.26	80 50.76	2.68	0.277E-03	0.152E-03			5
CE982A	35 10.20	80 50.75	2.96	0.266E-02	0.146E-02	0.345E-03	0.24	12
CE982B	35 10.20	80 50.75	2.64	0.970E-04	0.534E-04			4
CE982D	35 10.20	80 50.75	2.75	0.131E-02	0.721E-03	0.447E-04	0.06	11
CE982E	35 10.20	80 50.75	2.65	0.657E-03	0.361E-03			11
CE982F	35 10.20	80 50.75	2.77	0.266E-02	0.146E-02	0.222E-03	0.15	12
CW70A	35 13.64	80 56.18	2.96	0.168E-03	0.924E-04			2
CW71	35 13.52	80 57.98	2.98	0.137E-03	0.753E-04			10
CW71B	35 13.52	80 57.98	2.97	0.143E-02	0.785E-03	0.909E-03	1.16	2
CW72	35 13.79	80 58.08	2.76	0.000E+00	0.000E+00			14
CW153	35 10.21	80 54.77	2.77	0.367E-02	0.202E-02	0.387E-03	0.19	5
CW156	35 8.17	80 53.34	2.55	0.253E-02	0.139E-02	0.520E-04	0.04	5

SAMPLE	LAT.	LONG.	DEN.	MAG.SUS.	JI	Jr	Q	RX
CW1023	35 10.29	80 54.34	2.71	0.324E-02	0.178E-02	0.176E-03	0.10	5
CW1024	35 11.39	80 54.90	2.73	0.176E-02	0.967E-03	0.632E-04	0.07	5
CW1024B	35 11.39	80 54.90	2.87	0.933E-02	0.513E-02	0.591E-03	0.12	10
CW1067	35 7.69	80 55.90	2.97	0.614E-02	0.338E-02	0.820E-03	0.24	2
CW1097	35 11.57	80 56.60	2.68	0.128E-03	0.704E-04			5
CW1098	35 12.25	80 55.80	2.72	0.120E-02	0.662E-03	0.106E-03	0.16	19
CW1110	35 12.90	80 58.70	0.00	0.000E+00	0.000E+00			0
CW1111	35 12.62	80 58.98	2.96	0.000E+00	0.000E+00			4
CW1111B	35 12.62	80 58.98	2.90	0.276E-02	0.152E-02	0.164E-02	1.08	12
CW1111B1	35 12.62	80 58.98	0.00	0.000E+00	0.000E+00			10
CW1111B12	35 12.62	80 58.98	2.90	0.406E-02	0.223E-02	0.544E-03	0.24	12
CW1120	35 8.64	80 59.40	2.90	0.349E-02	0.192E-02	0.599E-03	0.31	2
CW1129	35 9.75	80 56.66	2.90	0.719E-02	0.396E-02	0.409E-02	1.03	1
CW1129A	35 9.70	80 56.60	2.94	0.714E-02	0.393E-02	0.399E-03	0.10	1
CW1129B	35 9.67	80 56.68	2.84	0.720E-02	0.396E-02	0.149E-03	0.04	15
CW1130A	35 10.62	80 57.04	2.69	0.311E-02	0.171E-02	0.303E-04	0.02	5
CW1130B	35 10.70	80 57.18	2.71	0.285E-02	0.156E-02	0.130E-02	0.83	5
CW1133	35 11.55	80 55.12	2.69	0.703E-03	0.387E-03			11
FM201	35 5.43	80 54.05	2.86	0.132E-02	0.723E-03	0.328E-01	45.40	1
FM204	35 4.20	80 52.70	0.00	0.000E+00	0.000E+00			9
FM205	35 3.84	80 52.63	2.98	0.940E-04	0.517E-04			3
FM1054	35 2.54	80 53.64	2.61	0.118E-03	0.649E-04			8
FM1035	35 2.32	80 52.96	2.62	0.600E-05	0.330E-05			15
FM1043A	35 1.40	80 55.13	2.66	0.819E-03	0.450E-03			8
FM1043B	35 1.40	80 55.13	2.98	0.590E-04	0.324E-04			2
FM1043C	35 1.40	80 55.13	2.68	0.000E+00	0.000E+00			8
FM1045	35 2.88	80 55.58	2.59	0.130E-04	0.715E-05			9
FM1046	35 3.26	80 55.70	2.84	0.400E-04	0.220E-04			3
FM1051	35 1.10	80 59.06	2.61	0.000E+00	0.000E+00			8
QFM1	35 6.45	80 55.23	2.98	0.130E-01	0.715E-02	0.127E-02	0.18	2
QFM2	35 6.45	80 55.23	2.93	0.928E-02	0.510E-02	0.461E-03	0.09	2
QFM3	35 6.45	80 55.23	2.63	0.325E-03	0.179E-03			8
QFM4	35 6.45	80 55.23	2.96	0.101E-01	0.557E-02	0.284E-03	0.05	2
QFM5	35 6.45	80 55.23	2.91	0.718E-02	0.395E-02	0.652E-03	0.17	2

SAMPLE	LAT.		LONG.		DEN.	MAG.SUS.	JI	Jr	Q	RX
QFM6	35	6.45	80	55.23	2.83	0.225E-02	0.124E-02	0.133E-03	0.11	2
QFM7	35	6.45	80	55.23	2.96	0.104E-01	0.571E-02	0.308E-03	0.05	2
QFM8	35	6.45	80	55.23	2.97	0.115E-01	0.635E-02	0.168E-02	0.26	2
QFM9	35	6.45	80	55.23	2.94	0.848E-02	0.466E-02	0.599E-03	0.13	2
QFM10	35	6.45	80	55.23	0.00	0.000E+00	0.000E+00			15
QFM11	35	6.45	80	55.23	2.95	0.818E-02	0.450E-02	0.188E-03	0.04	2
QFM12	35	6.45	80	55.23	2.96	0.103E-01	0.566E-02	0.367E-03	0.06	2
QFM13	35	6.45	80	55.23	2.95	0.725E-02	0.399E-02	0.641E-03	0.16	2
QFM1063A	35	6.45	80	55.23	2.86	0.590E-02	0.325E-02	0.171E-03	0.05	2
QFM1063A1	35	6.45	80	55.23	2.97	0.874E-02	0.481E-02	0.502E-03	0.10	2
QFM1063B	35	6.45	80	55.23	2.76	0.428E-02	0.236E-02	0.844E-03	0.36	3
QFM1063C	35	6.45	80	55.23	2.98	0.552E-02	0.304E-02	0.399E-03	0.13	2
QFM1063D	35	6.45	80	55.23	2.76	0.174E-02	0.959E-03	0.165E-01	17.19	10
FM1060	35	5.57	80	54.42	2.82	0.171E-02	0.940E-03	0.378E-01	40.20	1
LW279	35	7.20	81	7.30	2.60	0.190E-04	0.104E-04			20
LW279D	35	7.45	81	7.25	2.88	0.109E-02	0.601E-03	0.369E-03	0.61	12
LW279D1	35	7.45	81	7.25	2.97	0.677E-02	0.373E-02	0.125E-02	0.33	3
LW1145A	35	6.60	81	5.40	2.75	0.239E-02	0.131E-02	0.470E-03	0.36	4
LW1145B	35	6.60	81	5.40	2.95	0.168E-03	0.924E-04			10
LW1150	35	3.65	81	7.31	2.61	0.000E+00	0.000E+00			11
LW1151	35	4.40	81	6.18	2.61	0.000E+00	0.000E+00			14
M499	35	9.93	80	35.52	2.81	0.120E-04	0.660E-05			11
M519	35	12.30	80	33.30	2.79	0.550E-04	0.303E-04			12
M903	35	9.30	80	30.65	0.00	0.000E+00	0.000E+00			13
M911	35	14.93	80	33.78	0.00	0.000E+00	0.000E+00			0
M912	35	14.25	80	32.70	2.83	0.000E+00	0.000E+00			20
M912A	35	14.39	80	32.30	2.51	0.000E+00	0.000E+00			12
M912B	35	14.83	80	32.30	2.72	0.100E-04	0.550E-05			11
M924	35	12.75	80	33.58	0.00	0.000E+00	0.000E+00			13
M932	35	8.50	80	34.92	2.94	0.550E-04	0.303E-04			2
M932A	35	8.08	80	35.50	2.94	0.550E-04	0.303E-04			12
M932B	35	8.50	80	34.92	2.61	0.000E+00	0.000E+00			14
M936	35	7.80	80	36.07	2.82	0.710E-04	0.391E-04			12
M938	35	8.60	80	35.41	2.79	0.460E-04	0.253E-04			12
MA479	35	3.45	80	43.72	2.61	0.110E-04	0.605E-05			5

SAMPLE	LAT.		LONG.		DEN.	MAG.SUS.	JI	Jr	Q	RX
MA483	35	3.96	80	40.05	3.01	0.650E-04	0.358E-04			21
MA812B	35	5.47	80	37.61	2.92	0.490E-04	0.270E-04			12
MA839	35	2.50	80	9.14	2.92	0.480E-04	0.264E-04			12
MA865	35	3.36	80	45.34	2.62	0.141E-02	0.774E-03	0.296E-03	0.38	8
MA812	35	6.25	80	37.88	2.74	0.610E-04	0.335E-04			11
MA873	35	1.42	80	41.54	2.91	0.480E-04	0.264E-04			12
MA873A	35	1.35	80	41.51	0.00	0.000E+00	0.000E+00			21
MA854	35	5.41	80	41.73	2.64	0.740E-04	0.407E-04			5
MA855	35	5.28	80	41.96	2.61	0.126E-03	0.693E-04			5
MA856	35	5.95	80	42.42	2.67	0.357E-03	0.196E-03			11
MA856A	35	6.35	80	42.68	2.65	0.252E-03	0.139E-03			11
MA856B	35	6.00	80	42.00	3.01	0.462E-03	0.254E-03			12
MA868	35	0.87	80	44.88	2.61	0.884E-03	0.486E-03			8
MA873C	35	1.24	80	41.34	0.00	0.000E+00	0.000E+00			15
MA876A	35	1.65	80	43.00	2.59	0.323E-03	0.178E-03			19
MA876B	35	1.65	80	43.00	2.91	0.496E-02	0.273E-02	0.528E-02	1.94	21
MA876C	35	1.65	80	43.00	2.99	0.384E-02	0.211E-02	0.222E-02	1.05	21
MA877	35	2.43	80	42.46	0.00	0.000E+00	0.000E+00			11
MH510	35	11.95	80	38.08	0.00	0.000E+00	0.000E+00			5
MH540	35	11.92	80	43.90	2.62	0.900E-05	0.495E-05			14
MH763	35	14.00	80	42.25	2.79	0.250E-02	0.138E-02	0.536E-03	0.39	4
MH765	35	10.74	80	43.48	2.67	0.405E-03	0.223E-03			5
MH767	35	9.65	80	41.98	2.94	0.690E-04	0.380E-04			9
MH775	35	13.33	80	40.13	0.00	0.000E+00	0.000E+00			5
MH775B	35	13.05	80	40.02	2.69	0.000E+00	0.000E+00			11
MH775B1	35	13.05	80	40.02	2.87	0.143E-03	0.786E-04			11
MH888	35	12.37	80	38.90	3.23	0.550E-04	0.303E-04			15
MH889B	35	11.95	80	40.65	2.77	0.000E+00	0.000E+00			11
MH890	35	13.10	80	39.76	2.69	0.100E-04	0.550E-05			11
MH891	35	12.53	80	42.36	2.97	0.140E-02	0.771E-03	0.467E-03	0.61	3
MH891B	35	12.54	80	42.37	3.07	0.740E-04	0.407E-04			3
WKF1	35	0.82	80	49.18	2.96	0.980E-04	0.539E-04			15
WKF2	35	0.92	80	49.16	2.85	0.474E-02	0.261E-02			1
WKF2A	35	0.88	80	49.09	2.89	0.480E-02	0.264E-02	0.312E-02	1.18	1
WKF3	35	0.93	80	49.10	2.82	0.439E-02	0.242E-02	0.532E-02	2.20	1

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WKF3A	35	0.93	80	49.10	2.81	0.479E-02	0.263E-02			1
WKF3B	35	0.93	80	49.10	2.81	0.428E-02	0.235E-02	0.487E-02	2.07	1
WKF4	35	0.98	80	48.42	2.83	0.112E-02	0.617E-03	0.815E-03	1.32	1
WKF4A	35	0.98	80	48.42	2.82	0.790E-03	0.434E-03	0.815E-03	1.88	1
WKF5	35	0.75	80	49.10	2.87	0.750E-03	0.412E-03	0.922E-03	2.24	1
WKF5A	35	0.75	80	49.10	2.90	0.388E-02	0.214E-02	0.837E-02	3.92	1
W206	35	3.44	80	51.98	2.82	0.312E-03	0.172E-03	0.669E-03	3.90	2
W207A	35	2.95	80	50.14	2.62	0.504E-03	0.277E-03	0.109E-03	0.39	19
W207B	35	2.95	80	50.14	2.63	0.579E-03	0.318E-03	0.690E-04	0.22	19
W207B1	35	2.25	80	51.18	0.00	0.000E+00	0.000E+00			19
W207B2	35	2.25	80	51.18	0.00	0.000E+00	0.000E+00			19
W207C	35	2.95	80	50.14	0.00	0.000E+00	0.000E+00			19
W208	35	1.25	80	50.99	2.66	0.508E-03	0.279E-03			4
W209	35	0.01	80	52.35	2.59	0.225E-03	0.124E-03			4
W210C	35	5.26	80	51.32	2.90	0.555E-02	0.305E-02	0.544E-02	1.78	2
W210D	35	5.26	80	51.32	2.91	0.460E-04	0.253E-04			2
W210E	35	5.26	80	51.32	2.91	0.320E-04	0.176E-04			3
W210F1	35	5.26	80	51.32	2.97	0.127E-02	0.699E-03			2
W210F	35	5.26	80	41.32	2.59	0.520E-04	0.286E-04			9
W213A	35	5.72	80	47.14	2.94	0.112E-01	0.616E-02	0.109E-02	0.18	2
W213B	35	5.72	80	47.14	3.03	0.850E-02	0.468E-02	0.144E-02	0.31	2
W465	35	5.35	80	46.22	2.68	0.380E-04	0.209E-04			15
W466A	35	4.72	80	43.44	2.65	0.226E-02	0.124E-02	0.213E-02	1.71	7
W466AA	35	4.72	80	43.44	2.71	0.417E-02	0.229E-02	0.708E-03	0.31	6
W466B	35	4.62	80	46.95	2.95	0.112E-01	0.618E-02	0.175E-02	0.28	2
W466C	35	4.22	80	46.42	2.65	0.173E-02	0.951E-03	0.290E-04	0.03	6
W466E	35	4.77	80	46.80	2.63	0.100E-04	0.550E-05			7
W466E1	35	4.75	80	47.00	0.00	0.000E+00	0.000E+00			9
W471	35	5.90	80	45.88	0.00	0.000E+00	0.000E+00			15
W472	35	6.11	80	45.30	2.67	0.550E-04	0.303E-04			11
W995A	35	4.44	80	52.20	3.06	0.371E-03	0.204E-03	0.239E-04	0.12	18
W995B	35	4.44	80	52.20	2.82	0.941E-03	0.518E-03	0.143E-03	0.28	18
W997	35	1.50	80	52.10	2.69	0.504E-03	0.277E-03			15
W1002-1	35	0.57	80	49.14	2.96	0.340E-02	0.187E-02	0.116E-02	0.62	1

SAMPLE	LAT.	LONG.	DEN.	MAG.SUS.	JI	Jr	Q	RX
W1002-3	35 0.35	80 48.03	2.99	0.280E-02	0.154E-02	0.222E-03	0.14	1
W1003	35 0.35	80 48.03	2.90	0.199E-02	0.109E-02	0.225E-01	20.56	1
W1003A	35 0.35	80 48.03	2.93	0.250E-02	0.137E-02	0.336E-03	0.24	1
W1003B	35 0.33	80 47.98	2.94	0.290E-02	0.160E-02	0.446E-03	0.28	1
W1003X1	35 0.50	80 48.70	2.92	0.573E-02	0.315E-02	0.118E-01	3.75	1
W1003X2	35 0.50	80 48.70	2.95	0.696E-02	0.383E-02	0.751E-02	1.96	1
W1003X3	35 0.50	80 48.70	2.97	0.668E-02	0.367E-02	0.137E-01	3.72	1
W1003X4	35 0.50	80 48.70	2.97	0.653E-02	0.359E-02	0.484E-02	1.35	1
W1012	35 5.28	80 45.27	2.62	0.326E-03	0.179E-03			11
W1012A	35 5.28	80 45.27	2.64	0.108E-03	0.594E-04			19
W1013	35 3.57	80 45.10	2.72	0.149E-03	0.820E-04			19
W1013A	35 3.69	80 45.33	2.61	0.630E-04	0.347E-04			6