UNITED STATES DEPARTMENT OF THE INTERIOR
U. S. GEOLOGICAL SURVEY

Geologic Interpretation of Aeromagnetic Maps of the Coastal Plain Region of South Carolina and Parts of North Carolina and Georgia

by

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INTRODUCTION

Since 1975, the U.S. Coastal Plains Regional Commission has joined with the U.S. Geological Survey in a cooperative program to complete the airborne radiometric and magnetic surveying in the Coastal Plain regions of North Carolina, South Carolina, and Georgia. Recently Virginia and Florida have been added to the program.

This report covers the aeromagnetic data, and consists of a compilation of the data collected in the first two years of the program and the previous aeromagnetic surveys, with an interpretation of the geology of the basement rocks. The interpretation utilizes the aeromagnetic maps, samples from wells penetrating the basement, previous interpretations of the basement geology, and other geophysical data. The interpretation is presented on maps 3 and 4.

Aeromagnetic Data

The aeromagnetic maps (maps 1 and 2) are a compilation, at a scale of 1:500,000, of 15 different aeromagnetic total intensity surveys flown during the years 1958 to 1976. Of these, six surveys, comprising about one-half of the area, were funded by the Coastal Plains Regional Commission. Three older surveys were flown with a line spacing of one-half mile, and 12 with a one-mile spacing. All but one of the surveys had a flight elevation of 500 feet (150 m) above ground; that one was 1000 feet (305 m). A smooth regional magnetic gradient, the International Geomagnetic Reference Field (IGRF) (Fabiano and Peddie, 1969), has been removed from the data so that intensities are comparable. The contour interval is 10, 20, or 40 gammas on the newer surveys, and 100 gammas on several older surveys.

Samples from Basement Wells

Of the thousands of wells (water wells and oil tests) drilled into the Coastal Plain rocks, only a small percentage were deep enough to reach the basement, and not all of these have obtained samples of the basement rocks. Many of the early samples have been lost, so that identification by those who saw the rocks must be relied on. Occasionally, the basement was called "granite" when the drilling was slowed by hard rock, even though no samples were recovered. The rock so described could equally well be basalt, diabase, gabbro, gneiss, quartzite, or rhyolite. Most of the samples are in the form of cuttings, although some cores are available. Usually, the cuttings are contaminated with material caved from the upper part of the hole. The size of the cutting fragments is small, so that structures, such as metamorphic foliation, bedding, and faults can easily be missed. Therefore, the degree of uncertainty associated with well cuttings is much greater than for basement cores.

The writer examined as many samples as possible. Thin sections were prepared on many samples which had not been previously studied. Highly suspect data were not used. The basement well data is given in the appendix.

Previous Work

Many studies on the subsurface rocks have been done, particularly in Georgia, and reported in the literature. In Georgia, the basic work was done by Applin (1951), and the general picture put forth by him still stands. The data base was expanded considerably by Milton and Hurst (1965), and current work is being done by T.M. Chowns of West Georgia College (unpubl.). Geophysics has been used to support interpretations based on well data, for example, Skeels (1950), Woollard, Bonini, and Meyer (1957), Daniels (1974), Marine and Siple (1974), and Popenoe and Zietz (1977).

Geologic Setting

The Atlantic Coastal Plain is underlain by gently dipping sedimentary rocks of Mesozoic and Cenozoic age, which lie unconformably upon a basement similar to the adjacent Piedmont terrain. Because the basement includes sedimentary rocks, we use the term to include all Pre-Neocomian (Late Jurassic-Early Cretaceous) (Maher, 1971) rocks. The basement surface generally dips gently southeast, but may locally have a few hundred feet of relief. Structure contours on the basement surface (fig. 1) show some of the broad undulations. The Cape Fear and Peninsular arches are the high spots, while the thickest Coastal Plain sections are found at Cape Hatteras and the Southeast Georgia Embayment.

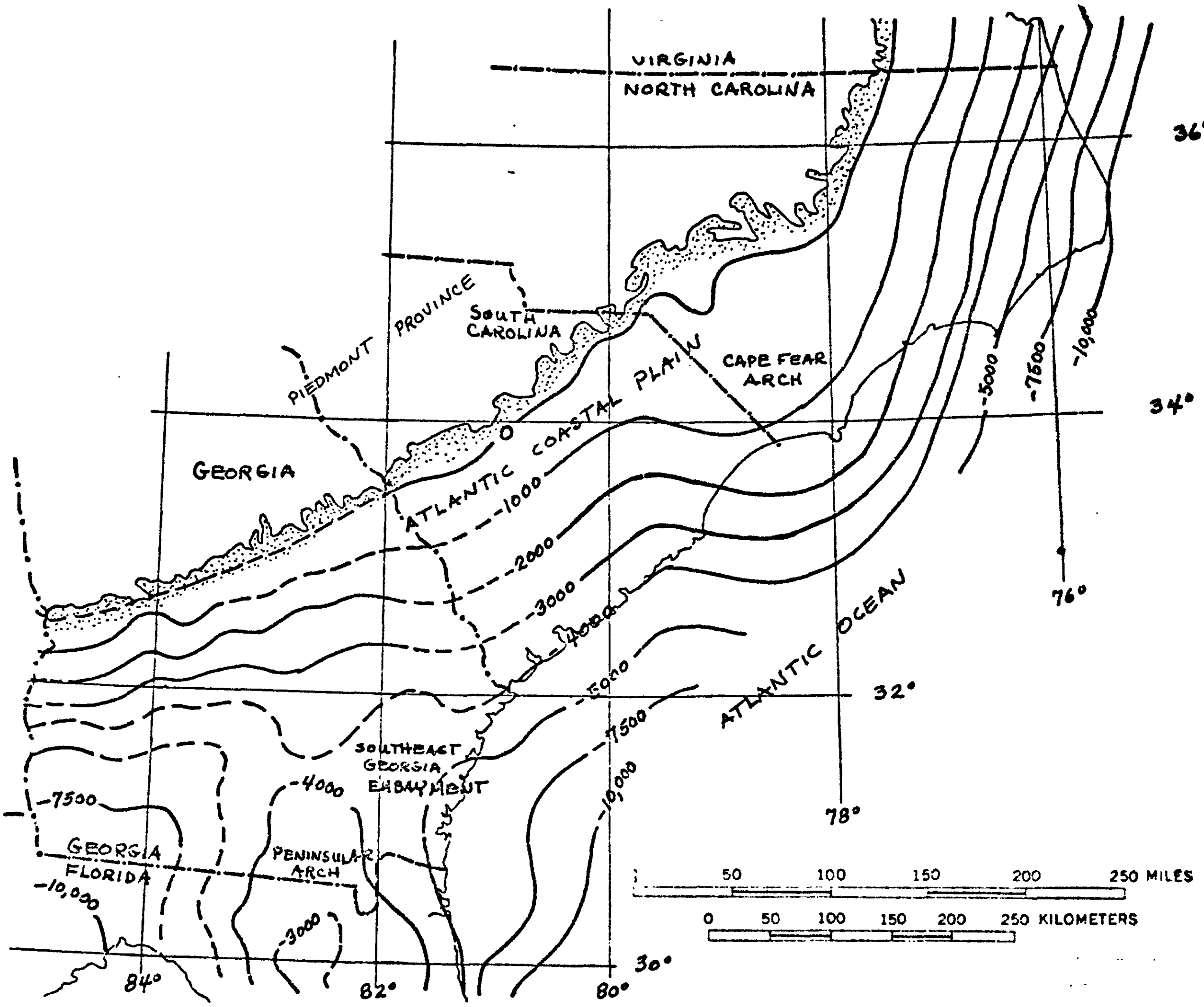

Figure 1 - Map showing Atlantic Coastal Plain and structure contours on top of pre-Cretaceous basement rocks, in feet. Modified from Maher (1971).

Because none of the Coastal Plain rocks are significantly magnetic, all of the magnetic anomalies on the aeromagnetic maps are due to magnetic contrasts within the basement. The only effect of the Coastal Plain rocks is to increase the distance between the airborne magnetometer and the anomaly-producing rocks.

"PIEDMONT" BASEMENT

Metamorphosed sedimentary and igneous rocks and associated intrusive plutonic rocks comprise the Piedmont Physiographic Province of the southeastern states. Similer rocks, herein called "Piedmont" basement, extend beneath the Coastal Plain rocks in each of the three states. Four aspects of these rocks are discussed as follows: (1) the extent of these rocks as mapped from wells and using the characteristic aeromagnetic "grain" of the Piedmont; (2) Piedmont belts, metamorphic grade, and granitic rocks using mostly well data; (3) basement structure based on the aeromagnetic maps; and (4) Triassic-Jurassic(?) diabase dikes.

Extent of the "Piedmont" Basement

A distinct pattern or "grain" is found on the aeromagnetic maps for much of the exposed Piedmont area. It is especially prominent near the Fall Line and in Georgia, and is characterized by narrow, linear anomalies with northeast trend (Popenoe and Zietz, 1977). The linear anomalies are generated by folded and faulted metamorphic rocks, but are absent where these rocks are non-magnetic or where interrupted by intrusive plutons. Most folding has occurred around nearly horizontal axes, resulting in map patterns dominated by long limbs of folds. Narrow anomalies are produced because only certain thin, upturned layers are significantly magnetic. Other narrow, linear anomalies may be produced by zones of cataclastic rocks (Hatcher and others, 1977).

Analysis of the aeromagnetic map of the Coastal Plain has revealed large areas in which the Piedmont "grain" is absent. Significantly, no foliated metamorphic rocks (the best indicators of Piedmont rocks) have been recovered from basement wells in these areas. Further, the contours are frequently broadly spaced, indicating large depth to the magnetic source rocks, and large amplitude anomalies are common. It is clear that there is a major difference between these areas and the Piedmont (Popenoe and Zietz, 1977). The line dividing these two areas for eastern South Carolina is shown in figure 2, based upon well data and the differences in magnetic grain. This interpretation assumes that all Piedmont type rocks in the basement have the magnetic grain necessary for identification.

Some of the lack of Piedmont grain may be attributed to the cover of Coastal Plain sediments, which steadily increase in thickness to the southeast. Narrow anomalies are most rapidly attenuated by the increase in distance to the source rocks. Such attenuation is probably severe only in southeast Georgia and near Cape Hatteras, where the Coastal Plain section is the thickest.

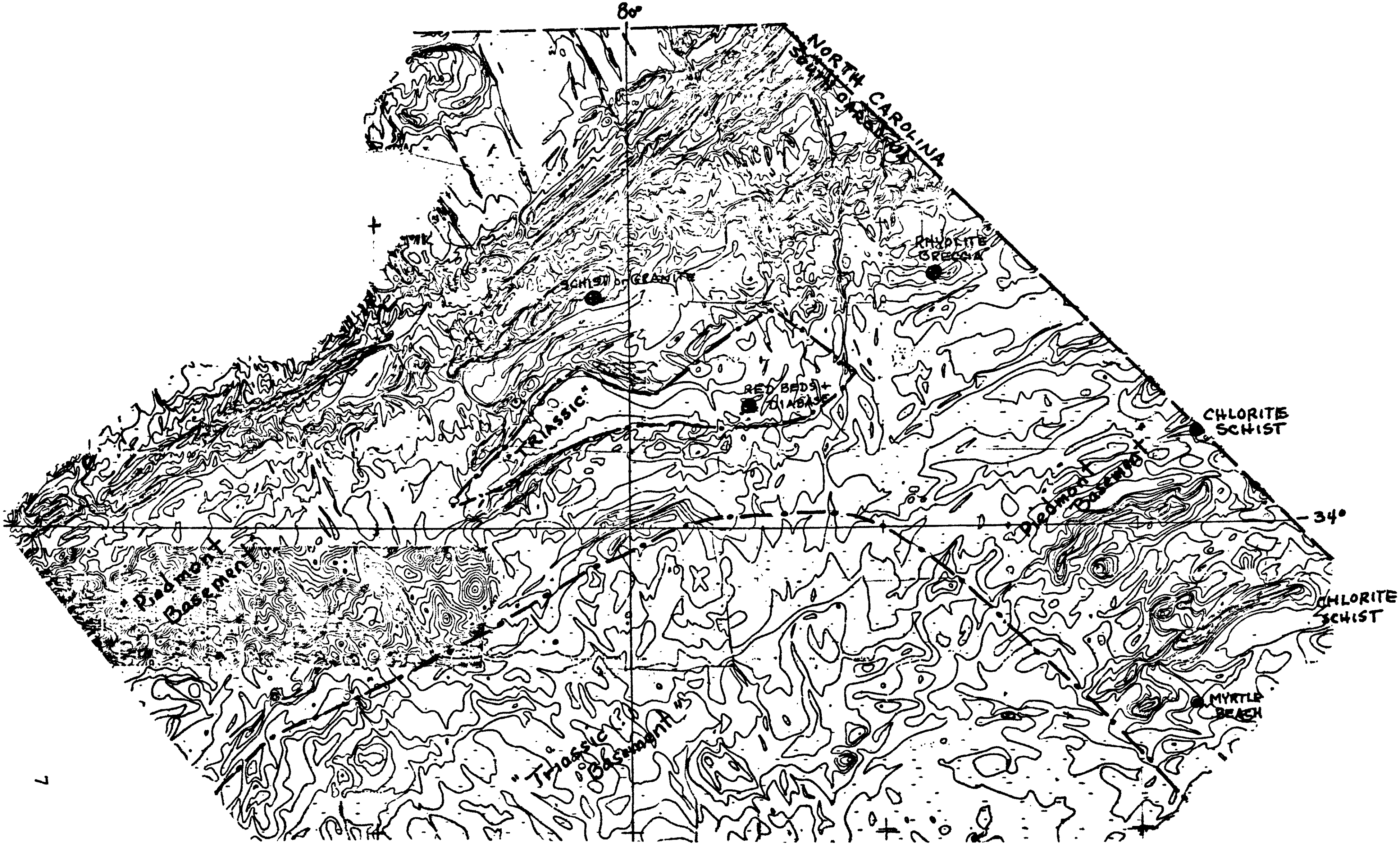

Figure 2 - Aeromagnetic map of the Coastal Plain of eastern South Carolina showing areas designated "Piedmont basement" and "Triassic(?) basement", in part modified from Popenoe and Zietz (1977).

It is interesting that the Piedmont basement, according to our interpretation, is very narrow in Georgia (as little as 15 miles (24 km)), and wide in North Carolina (apparently to the shelf edge). The line selected to separate the two areas travels northeast for a long distance, from Jeffersonville, Georgia, four miles (6 km) south of Waynesboro, Georgia, two miles (3 km) north of Orangeburg, South Carolina, then bends to the southeast 12 miles (19 km) south of Florence, South Carolina, and crosses the coast eight miles (13 km) southwest of Myrtle Beach, South Carolina (fig. 2).

Metamorphic Grade and Piedmont Belts

The exposed crystalline rocks of the southeastern states have customarily been separated for convenience into six geologic belts, each with different characteristics, based upon metamorphic grade, type of intrusives, and structural style (King, 1955; Butler and Ragland, 1969). The Carolina Slate belt is the principle belt discussed here. Additional belts have been described, mostly along the edge of the Fall Line, where the crystalline rocks are incompletely exposed: the Bel Air and Kiokee belts (Crickmay, 1952), the Raleigh belt, and the Eastern Slate belt (Parker, 1968; Cohee, 1962). The Carolina Slate belt, the Eastern Slate belt, and the Bel Air belt contain low-rank metasedimentary and metavolcanic rocks. The Raleigh and Kiokee belts are similar to the Charlotte belt, with amphibolite grade metamorphism and an abundance of plutonic rocks, but differ by the lack of gabbro plutons and associated mafic rock.

No strict correlation can be seen in the aeromagnetic data collected by the U.S. Geological Survey between metamorphic grade and intensity or abundance of magnetic anomalies over Piedmont rocks, contrary to the suggestion of Reed and others (1967). All information on metamorphic grade of the basement rocks comes from wells. The Piedmont basement in North Carolina and eastern South Carolina is predominantly low-grade, and a continuation of the exposed Carolina Slate belt and Eastern Slate belt. Gneiss from a well in Sampson County (Brown, 1958) and gneiss from a quarry on a buried monadonock(?) (Parker, 1968) at Fountain, Pitt County, North Carolina, may constitute a belt of higher-grade rocks, but the well data is too widely spaced to adequately define it. Quartzite also found at the Fountain quarry is quite magnetic, and may be generating the sharp magnetic anomaly found there.

The metamorphic grade apparently increases to the southwest across South Carolina. The well data again is too sparse to define this trend. With the exception of the Bel Air belt (Daniels, 1974), the basement rocks in Georgia are amphibolite grade, and may be part of the Kiokee or Uchee belts.

Granitic Rocks

Although granitic plutons are distributed throughout the exposed Slate belt (Stuckey, 1958; Overstreet and Bell, 1965; Pickering and Murray, 1976), and also recovered in scattered wells, a concentration of granitic rocks occurs in wells along the North Carolina coast. The abundance of granitic rocks, together with probable amphibolite grade country rock (biotite gneiss and garnetiferous schist) (Denison and others, 1967), suggests a distinct belt, herein informally designated the Hatteras belt (map 4). Aeromagnetic coverage is incomplete in this area, but a large gravity negative coincides with the northern part of the area (fig. 3) (Skeels, 1950; Krivoy and Eppert, 1977, U.S. Geol. Survey, 1968), which Watkins and Murphy (1973) conclude is caused by granitic rather than sedimentary rocks. However, a rapid increase in thickness in the Coastal Plain section (Brown and others, 1972) may be contributing to the exceptionally low values (-40 mgals) of this anomaly. A few radiometric age determinations on the rocks of the Hatteras belt indicate Precambrian-Paleozoic ages for the granitic rocks, and Paleozoic ages for metamorphic minerals, ages which are compatible with other Piedmont belts. Other very low Bouguer values occur offshore near Cape Fear, and may also be due to granitic rocks (fig. 3).

The majority of granitic plutons are non-magnetic, and either lack definition on aeromagnetic maps, or indicate their presence by lows with low gradients (example, Rolesville granite near Raleigh, North Carolina, fig. 4). A unique series of three granitic plutons, which intrude Slate belt rocks in a line near the Fall Line in South Carolina and North Carolina, are unusually magnetic (Popenoe and Zietz,

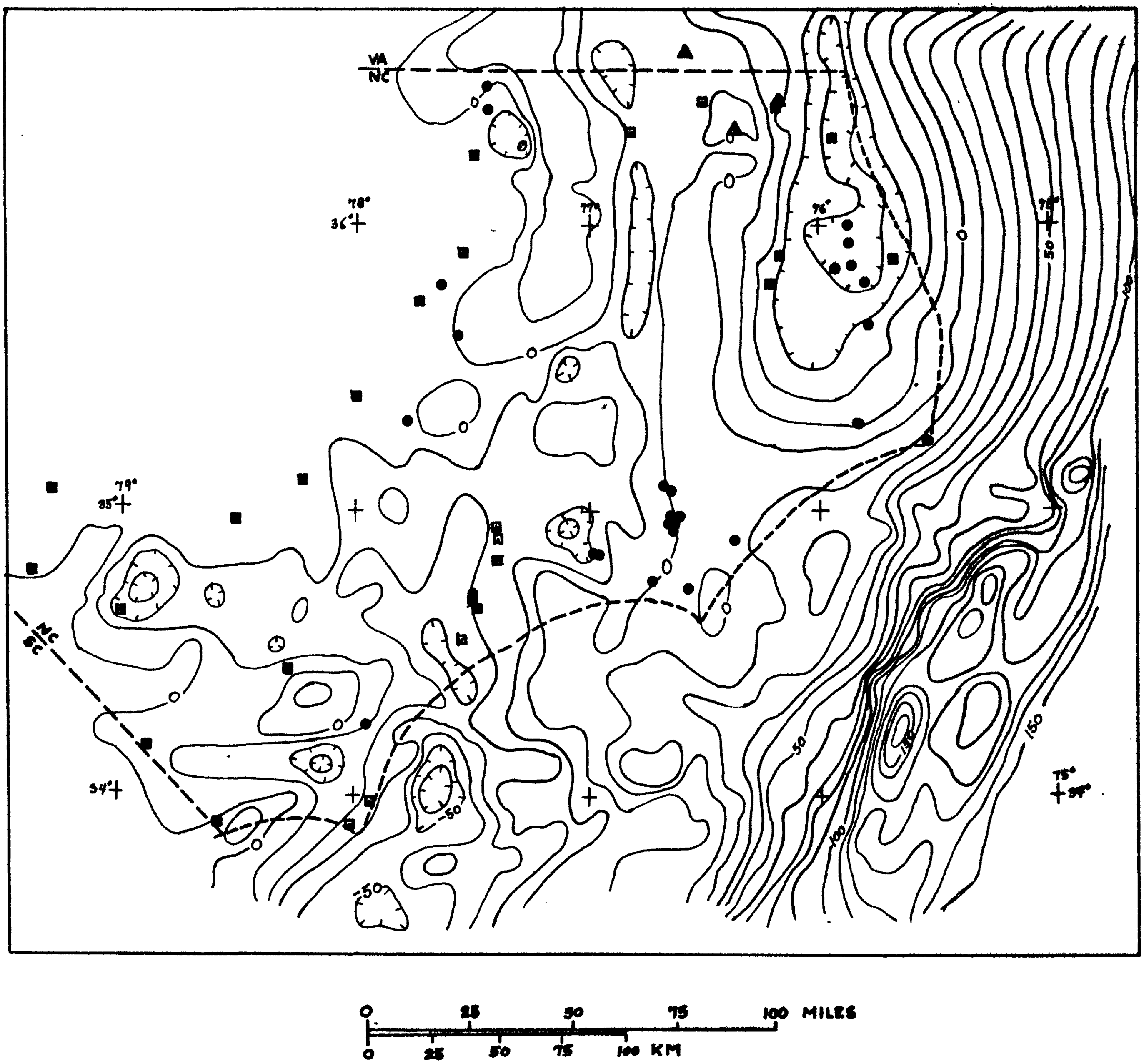

Figure 3 - Bouguer gravity map of the North Carolina Coastal Plain and offshore area (modified from Krivoy and Eppert, 1977, and U.S. Geol. Survey, 1968) showing relationship to rocks recovered from basement wells. Contour interval 10 milligals. Rock type of basement samples: circles-granitic rocks, squares-metamorphic rocks, triangles-Triassic rocks.

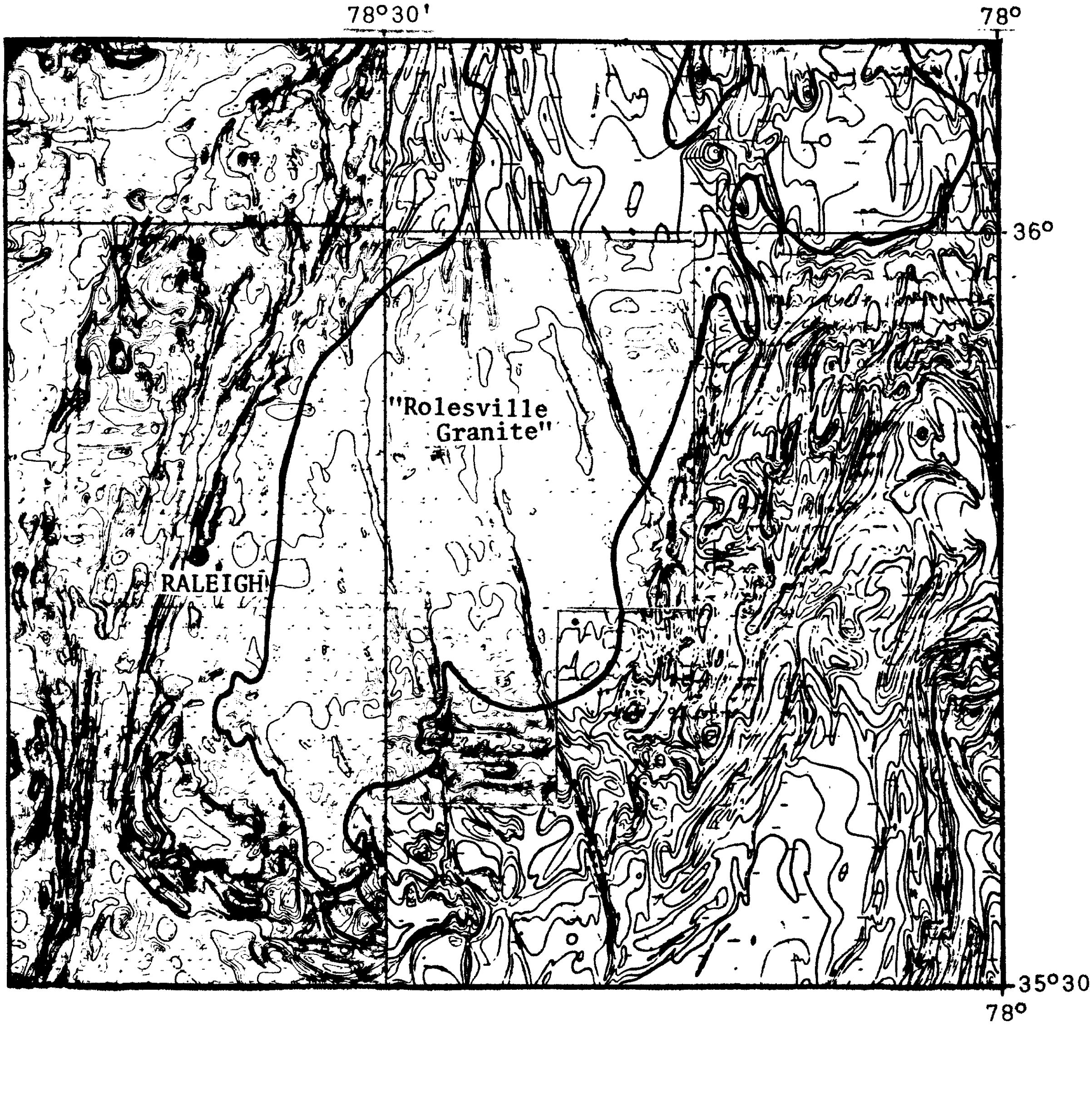

Figure 4 - Areomagnetic map of the Raleigh, North Carolina region with the boundary of the "Rolesville Granite" body superimposed (from Parker, 1968).

1977; Bell and Popenoe, 1976), and generate circular to oval magnetic highs. All three (Liberty Hill, Pageland, and Lilesville plutons) have radiometric ages of about 300 m.y. (Fullager, 1971; Bell and Popenoe, 1976), but apparently have a subtle difference from other non-magnetic 300 m.y. plutons in similar environments. The nearby 300 m.y. Winnsboro pluton, for which there is no aeromagnetic data, is similar, and may prove to be magnetic also. A similar circular magnetic high is associated with the Farrington pluton (Stuckey, 1958) in Orange County, North Carolina, but this is a much older intrusive (radiometric age 519 m.y., Fullager, 1971).

A large circular gravity low in Barnwell and Orangeburg Counties, South Carolina suggests a large granitic pluton (Popenoe and Zietz, 1977) or a series of plutons in the basement. No wells penetrate the basement here, but a local interruption of magnetic "grain" tends to support this interpretation (fig. 5). A similar gravity low is associated with the Rolesville pluton near Raleigh, North Carolina (Mann, 1962; Parker, 1968), and gravity lows of smaller dimensions with the Liberty Hill and Pageland plutons (Bell and Popenoe, 1976). A similar gravity low at Georgetown, South Carolina is also a possibility as granitic basement.

Structure

One of the unexpected features of the aeromagnetic maps is the bold pattern of linear anomalies near and east of the Fall Line in North Carolina. Most prominent are two nearly parallel groups of

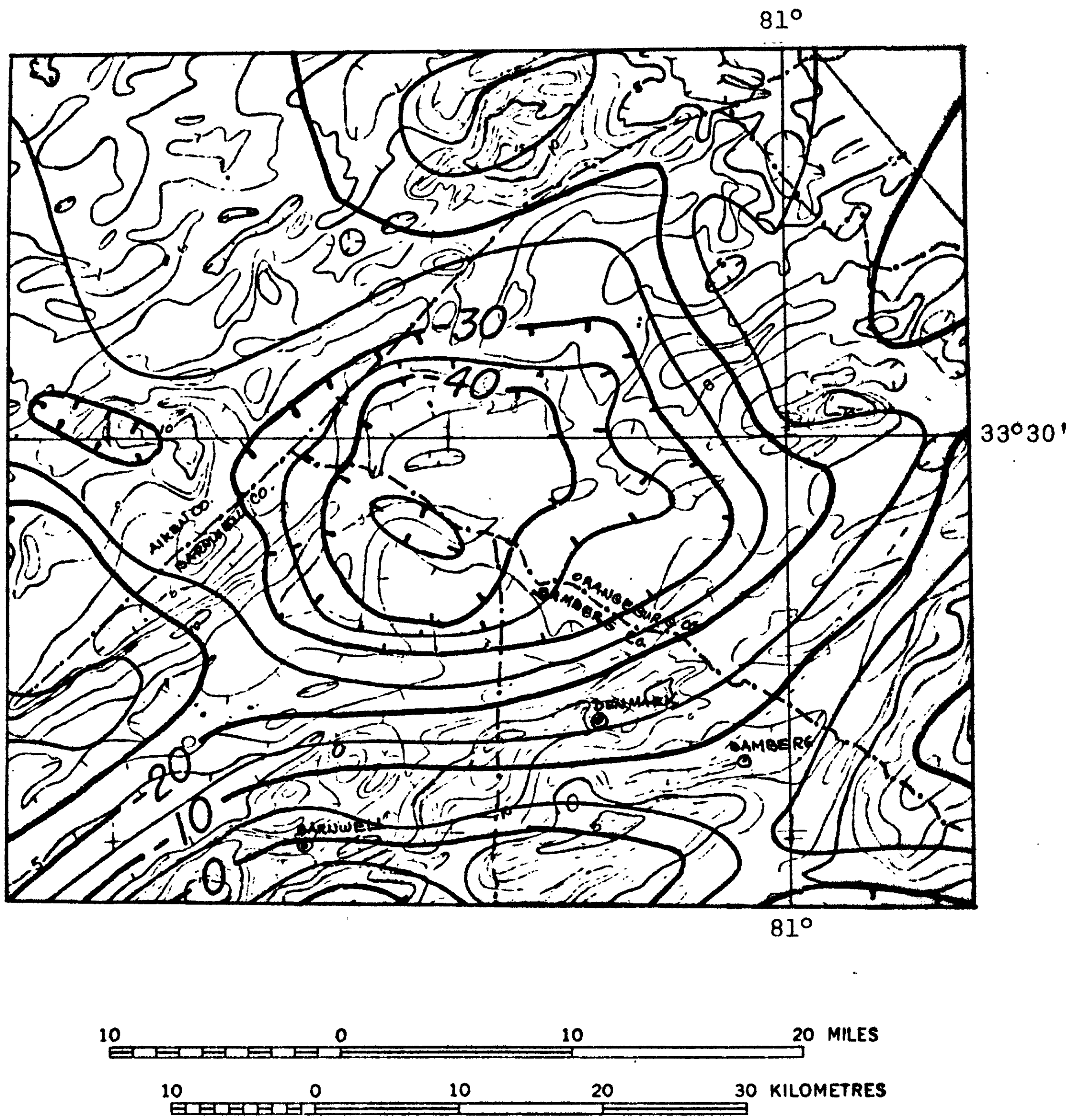

Figure 5 - Large gravity negative (hachured contours) in the South Carolina Coastal Plain. Gravity contours (heavy lines from Long and others, 1976, contour interval 5 milligals) superimposed on magnetic contours(contour interval - 100 gammas).

linear anomalies (A and B, fig. 6) 15 miles apart, which make a broad bend around the southern end of the Raleigh belt. One anomaly of the northern group closely corresponds to the eastern unit of quartzitic gneiss northwest of Raleigh, mapped by Parker and Broadhurst (1959). This anomaly merges with an anomaly that coincides with hornblende gneiss (fig. 6) (Wilson and others, 1975). It is not yet clear which of the two rock types is responsible for the continuation of the two anomalies. Comparison with other regions shows that similar linear magnetic anomalies coincide with mafic metavolcanic rocks of the Catoctin formation and also the Chopawamsic formation (Pavlides and others, 1974), both in Virginia. The anomaly follows the high-grade rocks around the southern end of the Rolesville pluton (Parker, 1968), while the second anomaly crosses terrain probably underlain by Slate belt rocks. The significance of these linear anomalies is realized by a comparison with the orientation of structures mapped on the ground (Parker, 1968). The anomalies are so closely parallel to these structures that the magnetic map can be considered a structure map. The magnetic map suggests that the rocks in the region have been bent into large-scale folds interrupted by north-south discontinuities. Hatcher and others (1977) consider the discontinuities to be part of an extensive eastern Piedmont fault system similar in nature and continuous with the Goat Rock fault in Georgia. A system of folds and faults is suggested in figure 6. Magnetic trends in the metamorphic rocks of the southeastern states rarely depart from the prevailing Appalachian trend (northeast

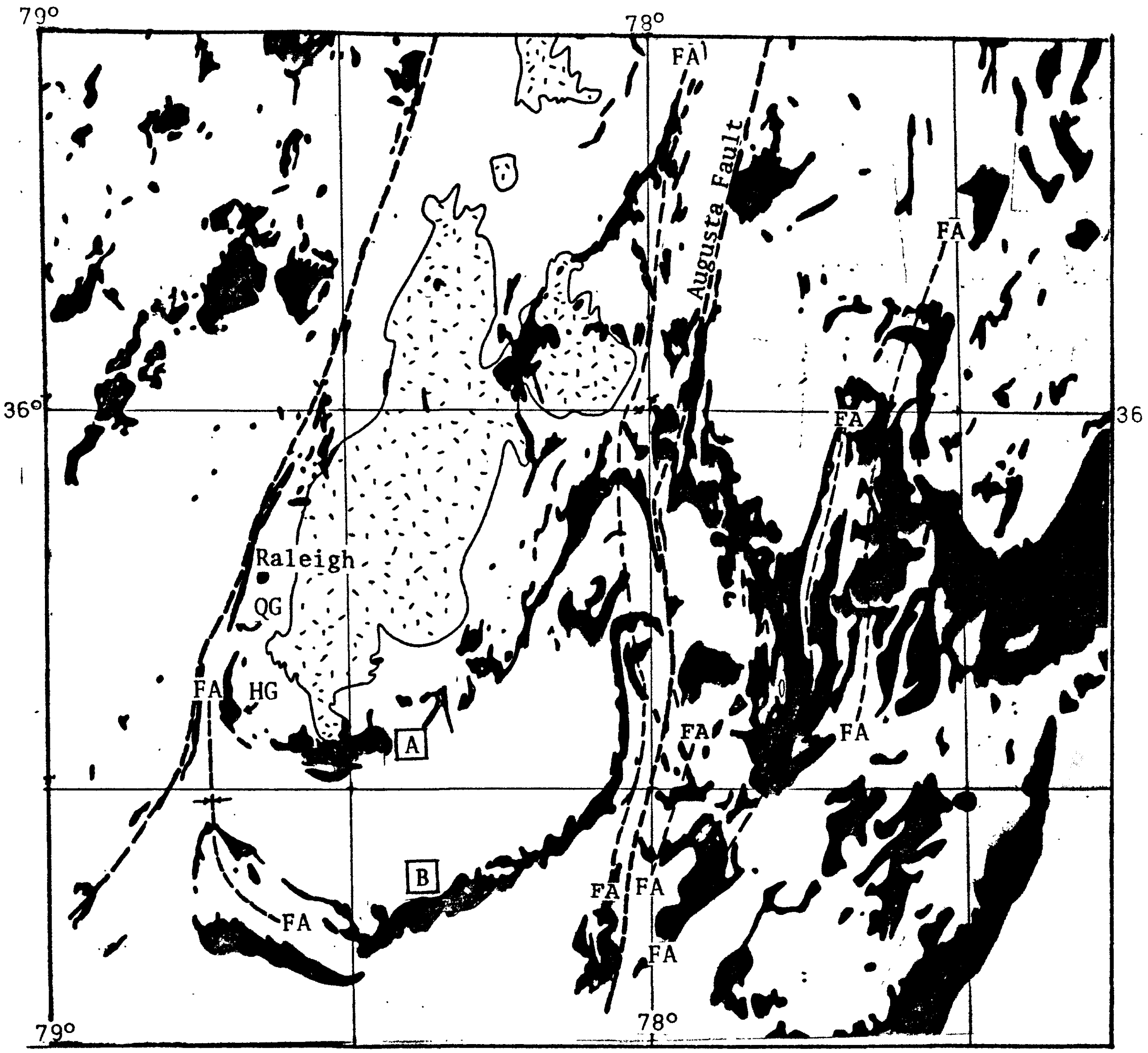

Figure 6 - Aeromagnetic map of the Piedmont and Coastal Plain region around Raleigh, North Carolina; magnetic intensities greater than -300 gammas (shaded pattern), less than -300 gammas (blank), showing granite bodies of the Raleigh belt (stippled pattern) after Parker (1968); inferred faults (heavy dashed lines) after Hatcher and others (1977); inferred fold axes (light dashed lines marked FA); anomaly associated with quartzitic gneiss after Parker and Broadhurst (195 marked QG); anomaly associated with hornblende gneiss, after Wilson and others (1975, marked HG).

to north). The broad deviations from this pattern of the anomalies marks the area east of Raleigh as structurally unique. Perhaps the Raleigh belt represents a competent micro-continent which resisted subduction and distorted the normal isoclinal fold pattern in the surrounding arc sediments and volcanics (Hatcher, pers. comm., 1977). Hatcher and others (1977) suggest that the prominent linear magnetic anomalies east and southwest of Columbia, South Carolina are part of their East Coast fault system. Daniels (1974) noted cataclastic rocks along the strike of one such anomaly near Batesburg, South Carolina.

Triassic-Jurassic(?) Diabase Dikes

In parts of the aeromagnetic map, the most striking anomalies are those produced by diabase dikes of Triassic-Jurassic(?) age. The anomalies are narrow and linear, and may be readily traced for long distances, especially where the country rocks are non-magnetic. They are most evident in the Piedmont, but many anomalies may be traced far out into the area which lacks the Piedmont magnetic grain. One group of anomalies extends from the Santee River north of Charleston, South Carolina due north to the Blue Ridge near Buena Vista, Virginia, a distance of about 300 miles (480 km). This particular swarm is unique, and the prominence of dikes with this orientation (north-south) was unknown before the aeromagnetic maps were produced. Since most dikes and the anomalies in the region trend north-northwest, two distinct ages are suggested. Alternatively, the two orientations may have been intruded in a single episode along a conjugate fracture pattern.

Linear anomalies, which are probably produced by Triassic-Jurassic diabase dikes, are identified on maps 3 and 4. The anomalies attributable to dikes are not evenly distributed. Some of this unevenness may be due to the Coastal Plain cover, to flight directions unfavorable to detection of these anomalies, or to interference from very magnetic country rocks, especially those which strike parallel to the dikes.

The greatest abundance of anomalies occur in the vicinity of the Liberty Hill, Pageland, and Lilesville granitic plutons along the Fall Line in northeast South Carolina and south-central North Carolina. The plutons probably represent the last igneous event in the area prior to the intrusion of the dikes, and may have been localized along a similar zone of weakness.

AREAS LACKING PIEDMONT MAGNETIC "GRAIN"

A considerable variety of pre-Cretaceous rocks have been identified from wells within the areas designated as lacking Piedmont "grain". These include rocks similar to sedimentary rocks from exposed Triassic basins often associated with basalt flows or diabase sills, felsic volcanic and plutonic rocks, and Paleozoic sedimentary rocks. The latter two groups are probably confined to southern Georgia. The "Triassic" sediments may extend throughout the remainder of the area, and probably overlie crystalline rocks.

Triassic-Jurassic Basins

Rocks of Triassic-Jurassic age (Van Houten, 1977) crop out along eastern North America in a series of fault-bounded basins, displacing crystalline rocks of the Piedmont and Paleozoic sedimentary rocks. Red-brown mudstones, arkoses, and conglomerates are the most common lithologies. Basalt flows in the upper part of the section and diabase sills are found abundantly in the region north of Virginia. Diabase dikes cut both Piedmont and Triassic sediments in a regular pattern from Alabama to Nova Scotia (King, 1971).

The existence of rocks of probable Triassic age beneath the Coastal Plain rock was recognized very early from deep wells which had penetrated the basement rocks (Darton, 1896, well at Florence, S.C.). Other early wells striking rocks that are probably Triassic were found in Summerville, South Carolina (Cooke, 1936), Laurens, Appling, and Montgomery Counties, Georgia (Applin, 1951), Camden County, North Carolina (Richards, 1954), and Barnwell County, South Carolina (Siple, 1967). Attempts to delineate the boundaries of these buried basins and to identify new basins have utilized additional drilling (Marine and Siple, 1974), gravity surveys (Marine, 1974), seismic refraction (Woollard and others, 1957; Bonini and Woollard, 1960), and magnetic surveys (McCarthy, 1936; Siple, 1967; Marine and Siple, 1974; Daniels, 1974; Popenoe and Zietz, 1977). Drilling is the preferred method of identifying basement rocks, but results in only point data, and is very expensive. However, none of the geophysical techniques is consistently reliable by itself because they depend on a contrast in physical properties between the basin rocks and country rock, which is not always present. On the basis of two low values for seismic velocity of basement rocks, Bonini and Woollard (1960) proposed a buried Triassic basin extending northeast from Raeford, North Carolina. However, all of the wells striking basement in the region were identified as Slate belt rocks (Schipf, 1964). If Triassic rocks do occur there, they must be restricted to very small areas in the vicinity of the seismic measurements.

On the basis of a ground magnetic survey, McCarthy (1936) stated that the Triassic rocks identified in the well at Florence, South Carolina extend from Lynchburg, South Carolina to Raeford, North Carolina, although the data was not shown. This trend seems contrary to the trends on the current aeromagnetic maps, and is further doubtful because of Slate belt rocks found in a well on this line at Maxton, North Carolina (Brown, 1958). We favor the shape for the Florence basin proposed by Popenoe and Zietz (1977) drawn on the basis of the aeromagnetic map (fig. 2).

Because of closer spacing of data and consistency of coverage, aeromagnetic surveys are better suited than ground magnetic surveys for such analysis. Siple (1967) inferred that an area of smooth contours and low magnetic intensity on an aeromagnetic map (Petty and others, 1965) defined the extent of a Triassic basin in Barnwell County, South

Carolina, based on one well which penetrated sediments identical in appearance to typical exposed Triassic rocks. Later drilling and coring of basement rocks (Marine and Siple, 1974; Marine, 1974) identified more Triassic rocks (named by them the Dunbarton basin), and corroborated the dimensions of the basin along a northwest-southeast line.

Additional geophysical data (seismic reflection, gravity, and ground magnetic surveys) collected in the same area suggest the Dunbarton basin is broken into a series of horsts and grabens (Marine, 1974). The southeast edge of the basin had been placed by Siple (1967) and Marine and Siple (1974) at the sharp gradient bounding a large area of intense magnetic highs. The model later offered by Marine (1974), however, removes this boundary, leaving the southeast extent of the Triassic rocks indefinite.

Depth calculations by the method of Vacquier and others (1951) on original aeromagnetic profiles puts the source of the anomalies southeast of the Dunbarton basin below the projected basement surface. The amount of cover on the anomaly-producing rocks, which may be Triassic sediments, varies from 640 meters on the northwest edge to 270 meters on the southeast edge (fig. 7). This is in general agreement with the model given by Marine (1974). We tentatively suggest, therefore, a veneer of Triassic sediments over the sub-basement rocks southeast of the Dunbarton basin.

Figure 7 - Aeromagnetic map of part of the South Carolina Coastal Plain showing locations of magnetic depth estimations (dots). These values were corrected for airplane and terrain elevations and then were averaged in the three boxed areas A, B, C. Each of the three average elevations of magnetic basement was subtracted from the average projected basement elevation as determined from well data and seismic refraction data (Woollard and others, 1957). The difference may represent the thickness of Triassic sedimentary rocks.

AREA	ELEV. OF MAGNETIC BASEMENT (METERS)	minus	PROJECTED ELEV. OF BASEMENT (METERS)	=	THICKNESS OF TRIASSIC(?) SEDIMENTS (METERS)
A	-980		-340		640
B	-700		-370		330
C	-790		-520		270

One of the more spectacular examples in the eastern states of aeromagnetic identification of a buried sedimentary basin occurs in an area southeast of Kinston, North Carolina. Low gradient and broad wavelength anomalies, indicating a large depth to the magnetic source, are sharply bounded by areas with numerous steep gradient anomalies, indicating much shallower depths. While no basement rocks have been recovered in the low gradient area, this almost certainly represents a buried Triassic-Jurassic basin (fig. 8). Two lines of evidence give strong support to this interpretation. First, surface faulting in Coastal Plain rocks has recently been observed (Brown and others, 1976) in parts of Craven and Lenoir Counties, North Carolina in a horst and graben arrangement. In addition, faulting near Kinston, North Carolina was suggested by Ferenczi (1959) related to the right-angle bend in the Neuse River. According to P.M. Brown and J.S. Sampair (pers. comm., 1977), the faults, they observed, are coincident with the northwest edge of the inferred basin. Rejuvination of the border faults of the buried basin appears to be the cause of the surface faulting. Our interpretation of the extent of the thickest part of the basin is shown in figure 8. The basin appears to thicken to the northeast, but a 40-mile (65 km) gap in the aeromagnetic data prevents continuous tracing of this feature. However, similar low gradients are found on the next survey, indicating possible continuation of this basin. Further, probable Triassic rocks have been recovered in wells in Camden (well 029-1) (Richards, 1954) and

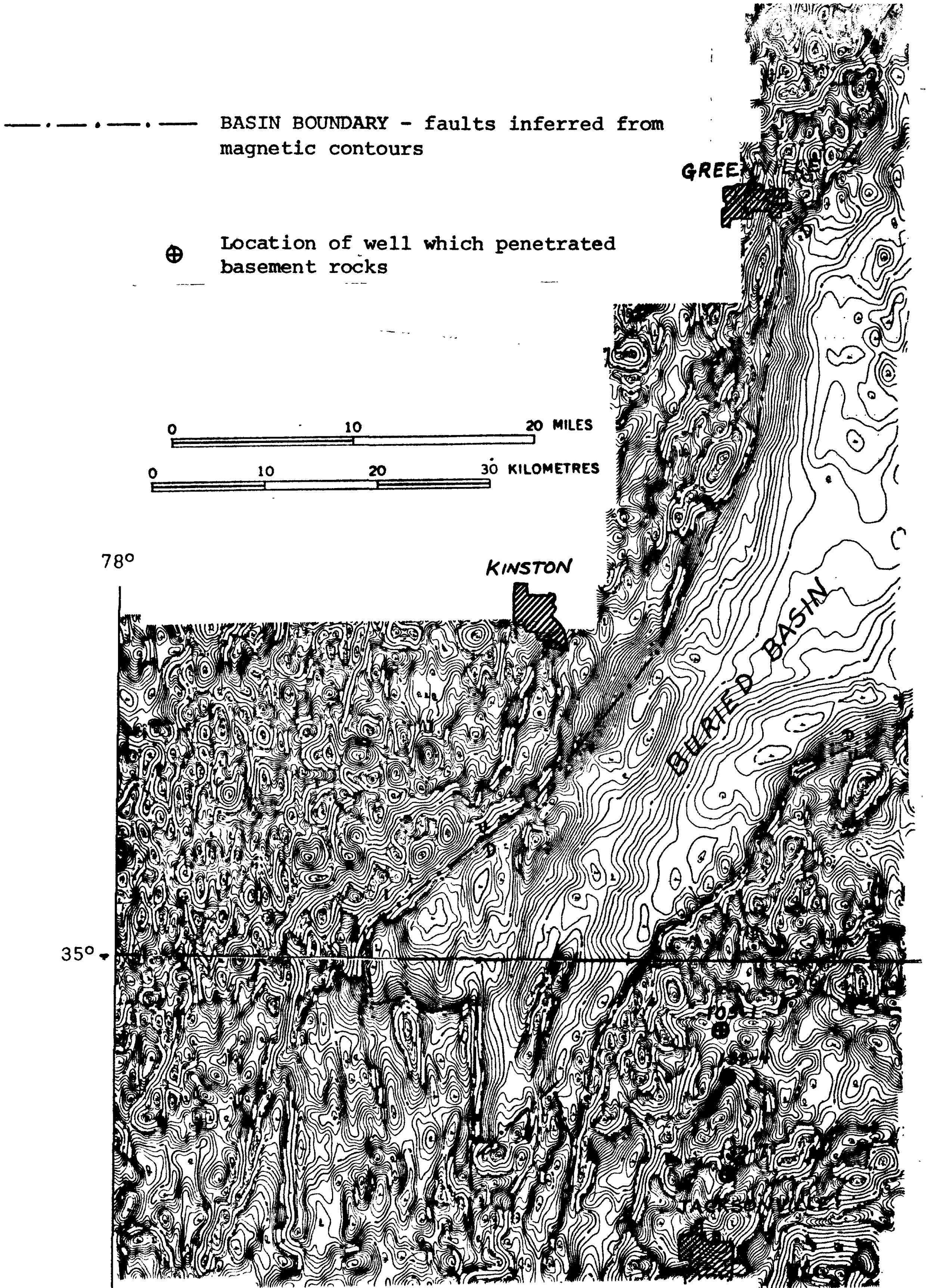

Figure 8 - Aeromagnetic map of the Kinston, North Carolina area showing the magnetic evidence for a Triassic basin beneath the North Carolina Coastal Plain.

Pasquotank Counties (well 131-1) in North Carolina and in Suffolk County, Virginia (Johnson, 1975), four miles north of the state line.

The examples just described illustrate that special conditions must be present where sedimentary basins may be identified by the magnetic contours. These conditions are: (1) strong magnetic contrast; since the Triassic sedimentary rocks are non-magnetic, the country rock must be moderately magnetic with an identifiable grain; (2) the basin must have considerable thickness, enough to suppress the magnetic grain of the basement; (3) the edges of the basin can be located only if they are marked by faults of large throw. Only part of the Durham-Wadesboro basin and none of the Dan River basin (Stuckey, 1958) is easily differentiated on aeromagnetic surveys. The magnetic contrast is absent when the surrounding Slate belt or Inner Piedmont belt rocks are non-magnetic.

It is to be expected, therefore, that the magnetic evidence for buried basins will usually be subtle, requiring supporting data to be convincing. As previously discussed in the section of Piedmont basement, a large part of the South Carolina and Georgia Coastal Plain is underlain by basement which lacks "Piedmont magnetic grain". In this large area, which includes the Dunbarton basin, no wells have brought up rocks most characteristic of the Piedmont, e.g., foliated schists and gneisses. Wells, mostly in Georgia, have encountered rocks similar to Triassic rocks elsewhere. On the basis of this evidence, together with the suppression of Piedmont-type magnetic anomalies, we suggest this entire area is probably underlain by Triassic sedimentary and mafic volcanic rocks, with the exception of the felsic igneous and Paleozoic sedimentary rocks in the south Georgia area. Although diabase and basalt occur in several Georgia and South Carolina wells, the magnetic anomalies associated with these rocks are probably small. Wells drilled by the U.S. Geological Survey near Charleston, South Carolina designed to core the basement rocks have penetrated basalt in three wells. The basalt layer was completely penetrated (255 m thick) in one, with recovery of red beds beneath (Gohn, pers. comm., 1977). Both are probably Triassic or Jurassic. The theoretical magnetic anomaly for a 50 km-wide sheet of basalt matching the properties of the basalt in the U.S. Geological Survey well is small (10-15 gammas), with narrow edge anomalies of 150 gammas (fig. 9). However, large amplitude anomalies are present in the Charleston area which would mask any anomalies produced by the Basalt. Basalt flows may be widespread in the basement, but the evidence is not present in the magnetic map. The large anomalies must be generated by rock bodies of large vertical dimensions, such as gabbroic intrusives in the basement beneath the red beds.

Talwani and others (1975) investigated the region around Georgetown, South Carolina with gravity and magnetic measurements, and interpreted the large gravity low there as a Triassic(?) sedimentary basin topped by a basalt flow, a structure very similar to that found in the U.S.

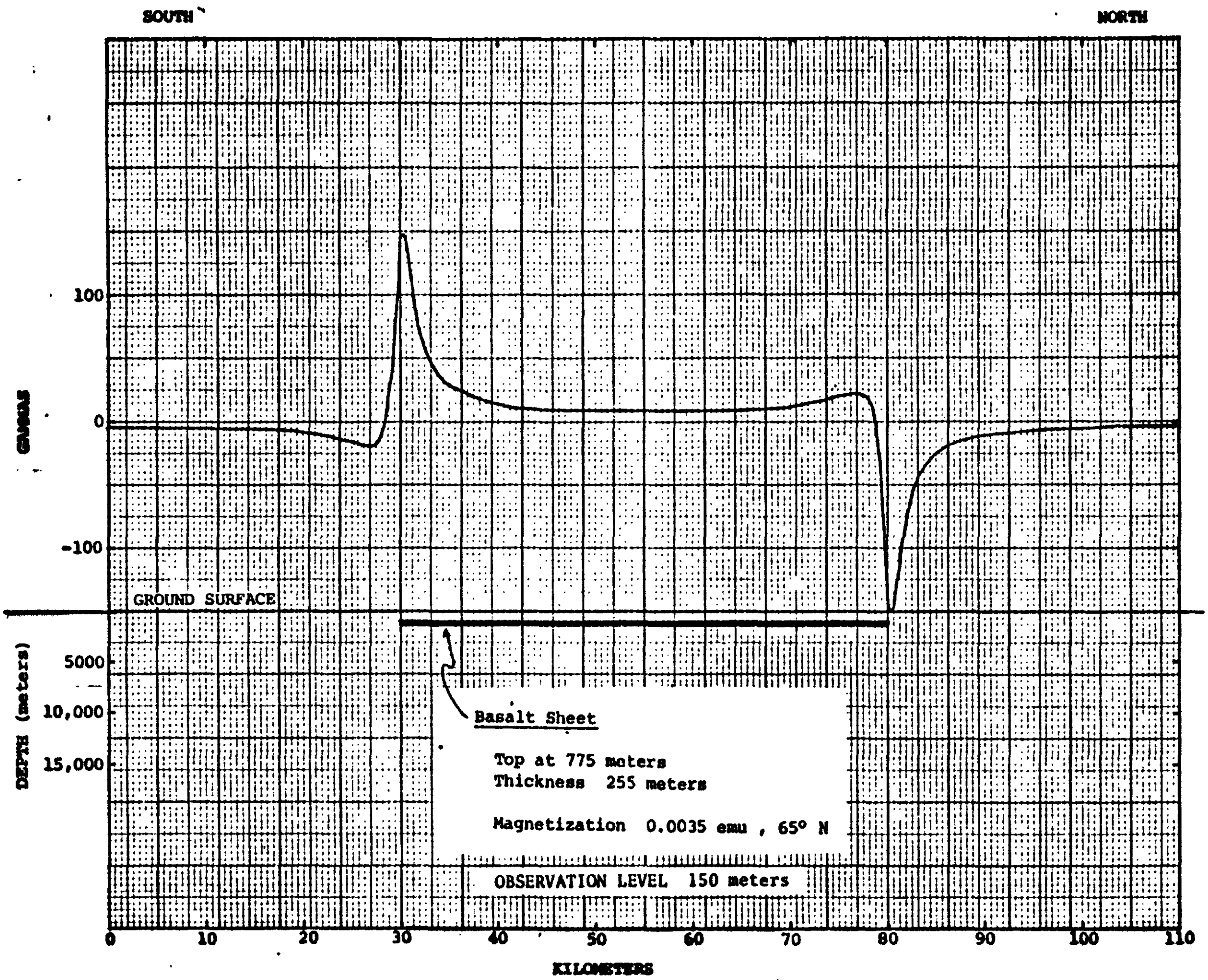

Figure 9 - Theoretical, two-dimensional magnetic anomaly produced by a sheet model matching the dimensions and magnetization of the basalt recovered from the U.S. Geological Survey wells near Charleston, South Carolina.

Geological Survey wells. Magnetic anomalies were measured, which can be interpreted as the edge effect of a basalt sheet. However, since Triassic basins in the exposed Piedmont cannot be consistently correlated with gravity lows, granitic rocks are a more likely interpretation.

Mafic Intrusives

Within the area lacking Piedmont magnetic "grain" are numerous large amplitude magnetic anomalies, many of which are associated with large gravity highs (Long and others, 1972, 1976). Also associated with these large amplitude highs are long wavelength magnetic anomalies resulting in large areas with elevated values (easily seen if the aeromagnetics are color coded). Since the rocks generating these anomalies have not been sampled by drilling, all our information about them comes from the geophysics. In part of the area, the moderate wavelength, high amplitude anomalies were designated mafic intrusives (Daniels, 1974; Popenoe and Zietz, 1977). The same criteria and designation are used in this report.

Most of these anomalies are oval or circular in outline, but a belt of anomalies south of the Dunbarton basin have a fragmented appearance, suggesting faulting subsequent to their emplacement. In Emanuel and Johnson Counties, Georgia, anomalies show striking evidence of being generated at several different depths (the shallowest sources produce the steepest gradients) (see fig. 10, points A, B, and C).

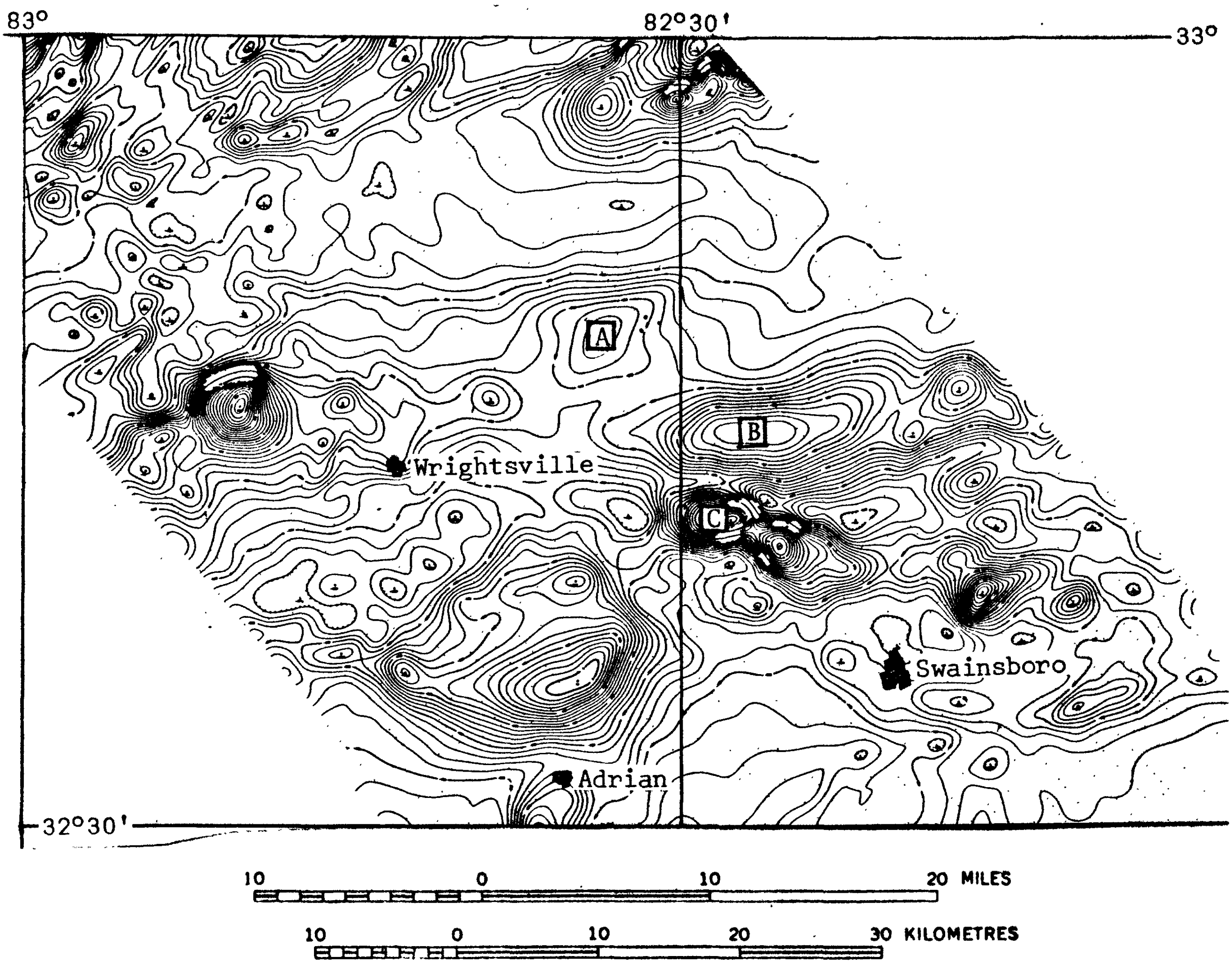

Figure 10 - Aeromagnetic map of part of the Coastal Plain of Georgia showing closely spaced magnetic anomalies generated by sources at different depths (points A , B , C).

The block-like appearance of the anomalies, together with the varying depths to the sources, suggest a horst and graben structure in the basement, probably generated in Triassic-Jurassic time, which is similar to the model given by Marine (1974).

Two wells only 2000 feet (600 m) apart in Treutlan County, Georgia, may have sampled the mafic rocks, but the data is ambiguous. One well recovered rocks of dioritic composition (GGS #789), while the second brought up an olivine-rich intrusive with diabasic texture (GGS #964). The first can be interpreted as either a mafic Piedmont rock or a mafic intrusive, and the second as mafic intrusive or Triassic-Jurassic(?) diabase. Since no significant associated magnetic or gravity anomalies are present, we interpret this as a Triassic-Jurassic(?) diabase sill, rather than a major mafic intrusive and uplifted Piedmont crystallines.

The close association of magnetic highs with Triassic rocks in this belt would seem to suggest that the major anomalies are generated by diabase. While this is possible, the large amplitudes of the gravity and magnetic anomalies requires considerable vertical extent, probably larger than any known intrusions of Triassic diabase. Instead, we suggest the mafic rocks may be of a type similar to the Baltimore State line complex in Maryland (Southwick, 1969), or various gabbro complexes in the Charlotte belt, from North Carolina to Georgia, such as the Concord (Bates and Bell, 1965), Buffalo and Mt. Carmel (Medlin, 1968), or Mecklenburg (Hermes, 1968) complexes. In support of this, a perfectly circular anomaly at the South Carolina coast southwest of Charleston is very similar to the anomaly produced by the Concord Syenite-gabbro complex in the North Carolina Charlotte belt (see fig. 11 showing both anomalies).

Three large amplitude, roughly circular gravity anomalies (Long and others, 1976) with a north-south alignment occur off the South Carolina coast, each with an associated magnetic anomaly (Taylor and others, 1968). The north-south alignment is anomalous, and suggests a history differing from the other anomalies. There may be significance or coincidence that this alignment is parallel to one set of Triassic diabase dikes.

The most puzzling aspect of this region is what constitutes the floor upon which the Triassic(?) rocks rest, and the source of the long wavelength magnetic anomalies. We have concluded that gabbroic plutons intrude these rocks, but the association with long wavelength anomalies has no exact counterpart in the exposed Piedmont. The proximity to the Piedmont and the slight northeast anomaly elongation of the anomalies nearest the Fall Line suggest affinity with the adjacent Piedmont rocks.

Felsic Volcanic and Plutonic Rocks

A poorly defined region of pre-Cretaceous felsic volcanic and plutonic rocks occurs in southeast Goergia (Ross, 1958; Milton and Hurst, 1965; Applin, 1951), bounded by Paleozoic sediments to the south and Triassic sedimentary and mafic igneous rocks to the northwest. Knowledge of these rocks comes solely from cuttings and cores from oil tests. Similar rocks are found in the central Florida basement

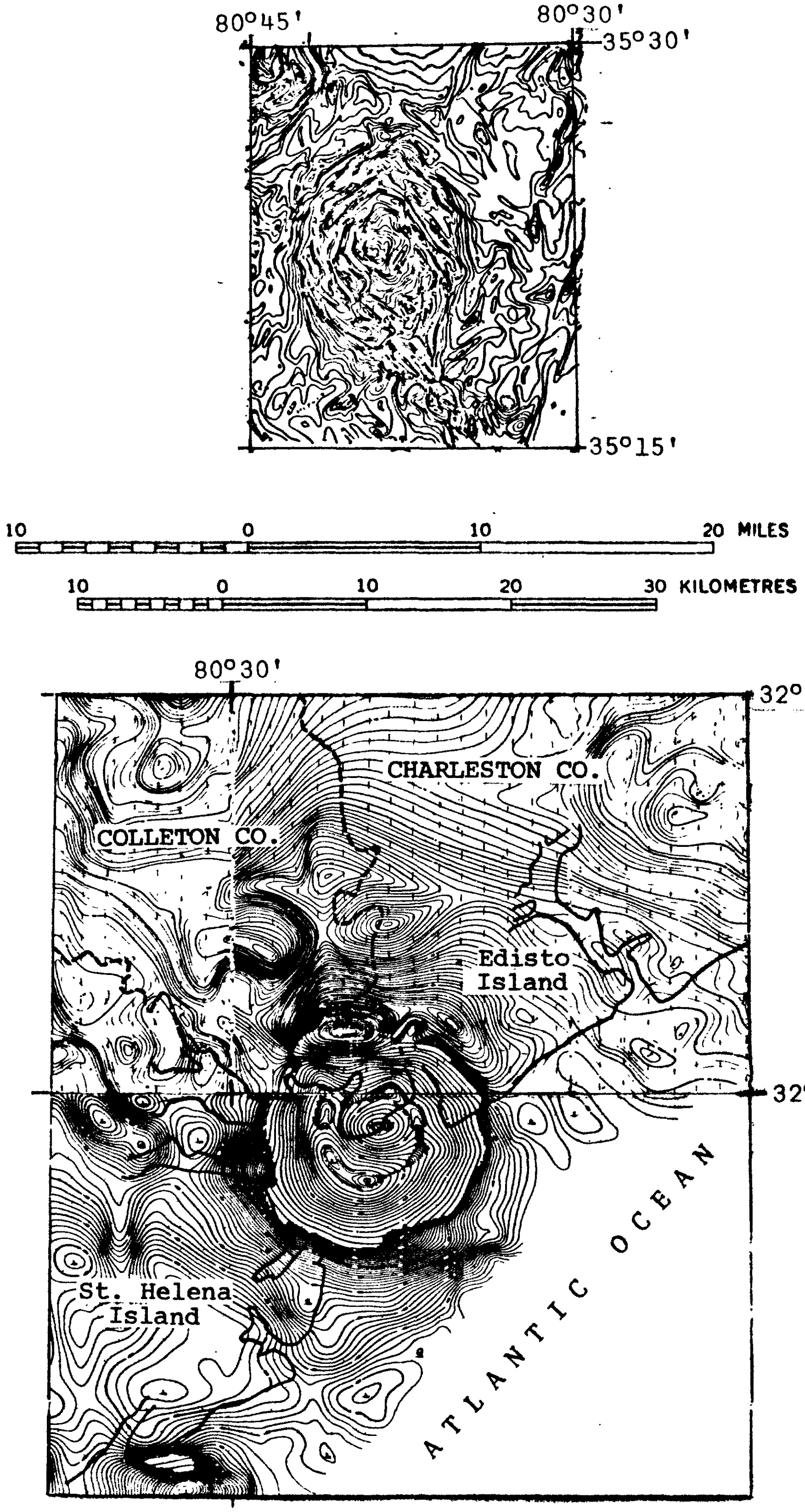

Figure 11 - Aeromagnetic map of an area southwest of Charleston, South Carolina, below, showing a circular anomaly similar to the anomaly over the Concord, North Carolina complex, shown above (Bates and Bell, 1965).

(Milton and Grasty, 1969; Applin, 1951; Barnett, 1975), which have a wider range in composition (rhyolite, andesite, basalt alaskite, granite, diorite). The age of the Georgia rocks is not reliably known, but their similarity to the Florida rocks suggests comparable ages. Two radiometric dates on rhyolites from Florida give Mesozoic ages (Osceola County, Humble Oil #1 Hayman, 173 m.y. K/Ar, Milton and Grasty, 1969; offshore Charlotte County Mobil #1 state lease 224B, 170 m.y. K/Ar, 212-228 m.y. Rb/Sr, Barnett, 1975). Mesozoic felsic volcanism is unknown elsewhere on the East Coast. These ages contrast with rhyolite tuff overlain by Ordovician sandstone (Marion County, Sun Oil, Camp #1, Applin, 1951), which requires a previous (pre-Ordovician) period of rhyolitic volcanism (Barnett, 1975).

Two distinctly different ages on granites from the Florida basement were also found (St. Lucie County, Amerada Pet., #2 Cowles Magazine, 226 m.y. K/Ar; Osceola County, Humble Oil, Carroll #1, 530 m.y., Milton and Grasty, 1969), and overlie the other rocks. While the dates of the Florida rocks suggest a genetic relationship between the granites and the rhyolites, it is possible that the Georgia granites are part of a crystalline basement, surrounded by grabens of sediments and volcanics.

The magnetic field in part of the rhyolitic area is remarkably smooth, requiring considerable depth to magnetic rocks, and is continuous with a triangular magnetically smooth area offshore to the east and another smooth area to the north. A thick basin of sedimentary rocks is suggested; the volcanics may be interbedded on top of the pile; Mesozoic or Paleozoic ages are both possible.

Brunswick Anomaly

A major offshore magnetic anomaly system, the East Coast magnetic anomaly, was shown by Taylor and others (1968) to be approximately aligned with the continental slope. South of Cape Hatteras, the anomaly leaves the continental slope and veers toward the coast. The anomaly character changes also. The well defined magnetic high over the continental slope is replaced by a series of short anomalies with different shapes, but associated with a very prominent and relatively continuous magnetic low. One segment of this high at Brunswick, Georgia coincides with a gravity anomaly of 15-30 mgals. Granite has been recovered from two wells in Pierce County, Georgia within another segment of the anomaly, yet the samples are non-magnetic. Apparently, the granite is not the cause of either the magnetic or gravity anomalies, which are probably being generated by a deeper rock body. A minimum thickness of 1200-2400 m of mafic rock is required to satisfy the gravity anomaly, assuming a 0.3 gm/cc density contrast. Pickering and others (1977) suggest that the source is either rift-filling mafic rock, presumably basalt, possibly generated during Triassic continental rifting, or the magma chamber of an old island arc.

At the coastline, the magnetic low is associated with rhyolitic rocks found in wells. This association may be true for the continuation of the anomaly.

Paleozoic Sedimentary Rocks

Unmetamorphosed sandstones and shales, some of which are Ordovician to Devonian in age based on sparse fossils (Bridge and Berdan, 1950; Applin, 1951), have been recovered from the pre-Cretaceous section from wells in northern Florida and southern Georgia. Only a small part of this area is covered by the current aeromagnetic surveys. The aeromagnetic contours are smooth, which is consistent with non-magnetic sediments covered with a thick Coastal Plain section. The area is too small, however, for meaningful geophysical analysis.

Cramer (1971) claims that the north Florida and southern Georgia Paleozoic sedimentary rocks have abnormal Silurian fossils compared with Silurian rocks in Alabama. Based on temperature sensitive phytoplankta and data on paleolatitudes, it appears that the Florida rocks were farther from the Alabama rocks by about 7° of latitude than they are now and are more like the assemblages of the lower Paleozoic of Guinea on the African Coast. The intervening space was occupied by the proto-Atlantic Ocean, which later closed to join the continental fragment to the Appalachian rocks.

ECONOMIC RESOURCES OF THE COASTAL PLAIN

Near-surface economic resources of the Coastal Plain rocks in the region of North Carolina to Georgia are abundant, and include ground water, heavy mineral sands, phosphate, clay and kaolin, limestone, and sand and gravel. Aeroradioactivity maps can be very useful in the search for some of these resources. On the other hand, aeromagnetic anomalies are rarely generated by shallow sources, and are completely dominated by contrasts within the basement rocks. There may be clues in the magnetic data to the location of deeper resources, such as petroleum, geothermal sources, or ground water, in so far as they are related to the lithology or structure of the basement rocks.

Cretaceous or younger faults which cut the basement rocks and some of the Coastal Plain rocks may produce traps favorable for petroleum accumulation. Surface faulting observed near Kinston, North Carolina (Brown and others, 1976) is probably related to faults in the basement which border a buried sedimentary basin (fig. 8). Similar faults may be common in the Coastal Plain section. Magnetic lineaments, some of which may be caused by basement faults, are shown on maps 3 and 4.

Popenoe and Zietz (1977) noted the close alignment between a strong magnetic lineament and the Orangeburg Scarp (Winkler and Howard, 1977) in South Carolina. Pickering and others (1977) have suggested that there may be structures favorable for petroleum accumulation on the flanks of the Brunswick anomaly.

Recently, studies of the Coastal Plain being carried out by L. Glover and J. Costain of the Virginia Polytechnic Institute have been aimed at locating economic geothermal sources generated by radiogenic heat from granitic plutons in the basement. The magnetic maps, together with gravity data, should be useful in this search.

SUMMARY

Basement wells and magnetic grain characteristic of Piedmont rocks indicate that Piedmont rocks extend beneath the Coastal Plain out to the North Carolina coast, but form relatively narrow zones in east Georgia and South Carolina. Although magnetic coverage is incomplete in much of eastern North Carolina, well data points to an extensive coastal belt of granitic rocks.

Linear magnetic anomalies which are parallel to Appalachian trends may trace long zones of mylonites in the Piedmont and in Piedmont-type basement (eastern Piedmont fault system, Hatcher and others, 1977).

Curvilinear anomalies south and east of the Raleigh belt in North Carolina probably delineate large fold systems in the metamorphic basement rocks.

Abundant and prominent linear anomalies, which cross the Appalachian trend and which can be traced far out into the Coastal Plain, are generated by diabase dike swarms of Triassic-Jurassic(?) age. Two distinct anomaly orientations are evident in central North Carolina; a north-northwest-south-southeast trend well known from geologic mapping, and a north-south trend not known to be important before the magnetic maps were available. The anomalies with north-south trend may be traced as a group for about 480 km, and may represent a separate period of dike intrusion.

Large areas of southeast Georgia and southern South Carolina lack the magnetic grain characteristic of Piedmont metamorphic rocks. Instead, circular or oval magnetic highs are common (many of which correspond to gravity highs), together with lower intensity regions of smooth, low-gradient magnetic contours indicative of large depths to magnetic rocks. The magnetic-gravity highs are probably caused by gabbroic plutons intruding an unknown basement, although no wells have verified this. Well data does indicate that continental-type sedimentary rocks accompanied by frequent diabase sills and basalt flows are present in parts of the area. Magnetic evidence suggests extensive block faulting along the northern part of the anomalous area.

The interpretation given here is that the entire area is underlain by a complexly faulted Triassic-Jurassic(?) rift system continuous with similar rocks in the Southwest Georgia Embayment (Barnett, 1975), and developed upon a variable basement, mafic plutons, and other rocks in the north, and felsic volcanic-plutonic and Paleozoic sedimentary basement to the south.

Smaller subsidiary basins may have developed upon a Piedmont basement; the Dunbarton basin is probably continuous with the main system of Triassic-Jurassic(?) rocks, while the Florence basin may be separated by a narrow band of Piedmont rocks. The basin at Kinston, North Carolina is probably similar and continuous with Triassic(?) rocks found in Virginia, although the magnetic data is incomplete.

Paleontological evidence indicates that the Paleozoic sedimentary rocks south of the Brunswick anomaly were separated from the North American continent during Silurian time by a Proto-Atlantic ocean. The suture between the Florida block and the North American block probably lies beneath Triassic-Jurassic sediments, and may be related to the Brunswick anomaly.

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APPENDIX DATA ON WELLS WHICH PENETRATE BASEMENT ROCKS

(The wells listed here are shown on maps 3 and 4. References cited in the appendix are listed at the end. Rock type data for each well comes principally from reference given under sources of data. Other facts about each well from Coffee (1977) for North Carolina and Marsalis (1971) for Georgia. Elevation and depth given in feet and (meters). Datum for elevation is sea level. Latitude and longitude given in degrees-minutes-seconds. Rock type descriptions with an * are assumed to be driller's identifications.)

GEORGIA

WELL NO.	COUNTY	WELL NAME, OPERATOR LANDOWNER YEAR COMPLETED	LATITUDE LONGITUDE	TOTAL DEPTH	BASEMENT ELEVATION	BASEMENT ROCK TYPE (Interpretation)	PRINCIPAL SOURCE OF DATA	REMARKS
A	Jefferson	A.F. Lucas & Georgia Petroleum Oil Co. Black #1 1907	32-58-10 82-27-00 (approx.)	1143 (348)	-695(?) -212(?)	Diorite schist (Piedmont)	McCallie (1908)	
GGS 7	Bibb	Layne-Atlantic U.S. Govt #2 Cochran Flying Field 1941	32-42-12 83-39-12	509 (155)	-138 (-42)	Chloritic gneiss (Piedmont)	Thin section of cuttings from 505-509 feet	Fine-grained, slight foliation; altered plagioclase & K-feldspar 65%, quartz 20%, chlorite-epidote-opaques 15%
GGS 51	Laurens	Calaphor Manuf. Co. Grace McCain #1 1945	32-27-40 82-45-30	2548 (777)	-2252 (-686)	Diabase (Triassic)	Applin (1951) (Well #86)	Probably overlies Triassic sediments
GGS 52	Wayne	California Co. Brunswick Peninsular Corp #1 1944	31-23-28 81-48-32	4626 (1410)	-4497 (-1371)	Tuffaceous arkose	Thin sections of cuttings from 4614-4625 feet	Dark, tightly cemented clastic rock. Coarser clasts: quartz 30%, altered feldspar 30%, fine-grained volcanic(?) clasts 30%; fine-grained matrix 10%
GGS 94	Washington	Layne-Atlantic, City of Sandersville #5 1944	32-57-28 82-48-25	873 (266)	-406 (-124)	Crystalline rock (Piedmont)	LaMoreaux (1946)	
GGS 95	Toombs	Tropic Oil Co. Gibson #1 1945	32-08-55 82-21-55	3681 (1122)	-3465 (-1056)	Arkosic sandstone (Triassic)	Milton & Hurst (1965)	
GGS 119	Pierce	Pan American Production Co. Adams-McCaskill #1 1938	31-23-45 82-04-13	4375 (1334)	-4271 (-1302)	Altered biotite granite	Hurst (1960)	Magnetic susceptibility on three core pieces. $K \approx 0.03 \times 10^{-6}$ cgs/cc
GGS 120	Pierce	W.B. Hinton Adams-McCaskill #1 1939	31-26-25 82-03-44	4355 (1327)	-4273 (-1302)	Altered granite	Applin (1951) (Well #12)	Magnetic susceptibility measurements on weathered core fragments. $K \approx 0.06 \times 10^{-3}$ cgs/cc
GGS 129 130	Richmond	Virginia Machine & Well Co. Georgia Training School 1940	33-22-18 82-01-42 33-22-18 82-01-40	329 (100) 1200 (366)	-19 (-6) -26 (-8)	Low-grade metavolcanic phyllites (Piedmont)	Examination of cuttings from 310-329 feet	Fine-grained, foliated phyllites. (1) pale green quartz-sericite-feldspar-chlorite; (2) dark green-chlorite-epidote-actinolite-feldspar opaques
GGS 131	Burke	Scott Drilling Co. U.S. Geol. Survey #1 1946	33-14-10 81-56-30 (approx.)	682 (208)	-473 (-144)	Low grade schist? (Piedmont?)	Herrick & Counts (1968)	

WELL NO.	COUNTY	WELL NAME, OPERATOR LANDOWNER YEAR COMPLETED	LATITUDE LONGITUDE	TOTAL DEPTH	BASEMENT ELEVATION	BASEMENT ROCK TYPE (Interpretation)	PRINCIPAL SOURCE OF DATA	REMARKS
GGS 148	Appling	Felsenthal & Weatherford W.E. Bradley #1 1947	Location uncertain 31-52-46? 82-23-02?	4106 (1252)	-3846 (-1172)	Basalt (Triassic)	Applin (1951) (Well #84) Milton & Hurst (1965)	Probably overlies Triassic sediments
GGS 153	Camden	California Co. John A. Buie #1 1948	31-03-01 81-52-48	4960 (1512)	-4705 (-1434)	Rhyolite tuff	Applin (1951) (Well #28)	
GGS 190	Montgomery	J.E. Weatherford Lonnie Wilkes #1 1946	32-13-00 82-28-32	3443 (1049)	-3122 (-952)	Diabase (Triassic)	Applin (1951) (Well #88)	Probably overlies Triassic sediments
GGS 223	Washington	Middle Georgia Oil & Gas Co., Lillian B. #1 1921	32-59-10 83-00-15	605 (184)	+88 (+27)	Biotite gneiss (Piedmont)	Prettyman & Cave (1923) Herrick (1961)	
GGS 309	Richmond	Virginia Supply & Well Co. Hotel Bon Aire #1 1952	33-28-35 82-00-40	480 (146)	+172 (+52)	Chlorite schist (Piedmont)	Herrick (1961)	
GGS 316	Burke	Three Creeks Oil Co. W.G. Green #2 1923	33-10-30 81-56-30 (approx.)	1033 (315)	-752 (-229)	Weathered crystalline rock(?) (Piedmont?)	Prettyman & Cave (1923) Applin (1951) (Well #8)	
GGS 336	Wheeler	T.R. Davis Jordan Heirs #1 1956	31-58-50 82-38-47	4002 (1220)	-3695 (-1126)	Red & gray siltstone (Triassic)	Milton & Hurst (1965)	
GGS 357	Bibb	Layne-Atlantic Co. Strietmann Bisquit Co. #1 1953	32-47-00 83-38-28	303 (92)	+61 (+19)	Hornblende gneiss (Piedmont)	Thin sections of cuttings from 301-303 feet	Fine-grained, foliated-feldspar 40%; hornblende 30%; quartz 20%; biotite-chlorite 10%; opaques
GGS 361	Bibb	Layne-Atlantic Co. Dixie Dairies #1 1953	32-47-00 83-38-28 (approx.)	253 (77)	+56 (+17)	Crystalline rock (Piedmont)	Herrick (1961)	
GGS 363	Liberty	E.B. LaRue Jelks-Rogers #1 1954	31-41-15 81-20-45	4254 (1297)	-4224 (-1287)	Rhyolite porphyry	Milton & Hurst (1965)	
GGS 651	Wayne	Humble Oil & Refining Co. Union Bag & Paper #1 1960	31-31-20 81-41-05	4552 (1387)	-4291 (-1308)	Rhyolite tuff	Milton & Hurst (1965)	
GGS 719	Glynn	Humble Oil & Refining Co. W.C. McDonald #1 1961	31-14-46 81-38-00	4737 (1444)	-4685 (-1428)	Granite	Milton & Hurst (1965)	
GGS 730	Treutlen	Barnwell Drilling Co. James Gillis #1 1961	32-23-20 82-32-25	3240 (988)	-2702 (-824)	Quartzite? (Triassic?)	Marsalis (1970)	Very uncertain lithologic identification

APPENDIX (Georgia) (continued)

WELL NO.	COUNTY	WELL NAME, OPERATOR LANDOWNER YEAR COMPLETED	LATITUDE LONGITUDE	TOTAL DEPTH	BASEMENT ELEVATION	BASEMENT ROCK TYPE (Interpretation)	PRINCIPAL SOURCE OF DATA	REMARKS
GGS 789	Treutlan	McCain & Nicholson James Gillis #1 1962	32-21-41 82-28-40	3180 (969)	-2856 (-871)	Biotite gneiss or diorite (Piedmont or mafic basement)	Thin section of cuttings from 3170-3180 feet	Two chips of basement rock: (1) unfoliated, quartz 40%; plagioclase 30%; biotite 25%; muscovite 5%; opaques, garnet; (2) unfoliated, altered plagioclase 50%; quartz 30%; chlorite-opaques-muscovite 20%
964	Treutlan	McCain & Nicholson James Gillis #2	32-21-26 82-28-23	3253 (992)	-2800 (-853)	Olivine diabase or gabbro (Triassic or mafic intrusives)	Thin section of cuttings from 3120-3130 and 3190-3200 feet	Ophitic texture; olivine-partly altered to serpentine 40%; augite 30%; plagioclase slightly altered 30%; opaques, biotite
GGS 1198	Camden	Amoco Union Camp #1B 1970	30-50-40 81-51-25	4690 (1430)	-4593 (-1400)	Sandstone & siltstone (Paleozoic)	Barnett (1975)	
GGS 1199	Camden	Amoco Union Camp #1C	30-50-35 81-44-05	4597 (1401)	-4515 (-1376)	Sandstone & siltstone (Paleozoic)	Barnett (1975)	
GGS 3184	Richmond	Georgia Geol. Survey State of GA #C-5	33-19-20 82-12-06	445 (136)		Phyllite (Piedmont)	GGS files (1977)	
TW1	Richmond	US Army Corps of Engineers 1957	33-18-00 82-15-06		+95 (+29)	Biotite granite (Piedmont)	US Army Corps of Engineers (1957)	
TW2	Richmond	US Army Corps of Engineers 1957	33-21-24 82-08-54		+133 (+41)	Mica phyllite (Piedmont-Little River Series)	US Army Corps of Engineers (1957)	

VIRGINIA

WELL NO.	COUNTY	WELL NAME, OPERATOR LANDOWNER YEAR COMPLETED	LATITUDE LONGITUDE	TOTAL DEPTH	BASEMENT ELEVATION	BASEMENT ROCK TYPE (Interpretation)	PRINCIPAL SOURCE OF DATA	REMARKS
A	Nansemond		36-36-45 76-34-57	2020 (616)	-1870 (0570)	"Red Beds" (Triassic)	Teifke (1973) Johnson (1975) (#W-3316)	

APPENDIX (continued)

NORTH CAROLINA

WELL NO.	COUNTY	WELL NAME, OPERATOR LANDOWNER YEAR COMPLETED	LATITUDE LONGITUDE	TOTAL DEPTH	BASEMENT ELEVATION	BASEMENT ROCK TYPE (Interpretation)	PRINCIPAL SOURCE OF DATA	REMARKS
019-A	Brunswick	W.H. Gray Bros. Fort Carswell 1907	33-53-15 78-02-00 (approx.)	1543 (470)	-1532 (-467)	Low-grade schist (Piedmont)	Clark & others (1912)	
019-B	Brunswick	North Carolina State Calabash HH39, j-2	33-54-00 78-34-00 (approx.)		-1285 (-392)	Chlorite schist (Piedmont)	Preliminary examination of core	
029-1	Camden	DuGrandlee Explor. Co., Forman #1 1953	36-25-10 79-09-58	6421 (1957)	-2845(?) (-867?)	Red shales, diabase (Triassic)	Richards (1954)	
					-6370(?) (-1942?)	Quartzite (Piedmont?)		
029-2	Camden	E.F. Blair Weyerhaeuser #1 1965	36-24-40 76-10-30	3741 (1140)	-2814 (-858)	Foliated rhyolite tuff (Piedmont)	Allen & Wilson (1966); Denison & others (1967)	Rb/SR date 408±40 my whole rock Denison & others (1967)
031-1	Carteret	F.L. Karston Laughton #1 1945	34-45-40 76-45-30 (approx.)	4044 (1233)	-4013 (-1223)	Granite* (Piedmont)	Berry (1948)	
031-2	Carteret	Carolina Petroleum Co., Guy M. Carraway #1, 1946	34-57-15 76-38-06 (approx.)	4069 (1240)	-4035 (-1230)	Granite* (Piedmont)	Berry (1948)	
031-3	Carteret	Carolina Petroleum Nita Carraway #1 1946	34-55-50 76-38-05	4126 (1258)	-4106 (-1252)	Granite* (Piedmont)	Berry (1948)	
031-4	Carteret	Carolina Petroleum D.H. Phillips #1 1946	34-58-50 76-39-00	3964 (1208)	-3933 (-1199)	Granite* (Piedmont)	Berry (1948)	
031-5	Carteret	Carolina Petroleum H.B. Salter #1 1946	34-57-15 76-39-35	3963 (1208)	-3944 (-1202)	Granite* (Piedmont)	Berry (1948)	
031-6	Carteret	Carolina Petroleum John Wallace #1 1946	34-58-45 76-38-00	4024 (1227)	-4005 (-1221)	Granite* (Piedmont)	Berry (1948)	
031-8	Carteret	Coastal Plains Oil Bayland Corp. #1 1961	34-53-55 76-22-00	5609 (1710)	-5552 (-1692)	Granite (Piedmont)	Preliminary examination of cuttings from 5600-5607 feet	
031-9	Carteret	Coastal Plains Oil Huntley-Davis #1 1961	34-43-50 76-34-30	4965 (1513)	-4938 (-1505)	Granite (Piedmont)	Preliminary examination of cuttings from 4970-4975 feet	

WELL NO.	COUNTY	WELL NAME, OPERATOR LANDOWNER YEAR COMPLETED	LATITUDE LONGITUDE	TOTAL DEPTH	BASEMENT ELEVATION	BASEMENT ROCK TYPE (Interpretation)	PRINCIPAL SOURCE OF DATA	REMARKS
047-A	Columbus	North Carolina State Tabor City 1976(?)	34-09-00 78-52-45			Chlorite schist (Piedmont)	Perry Nelson (pers. comm., 1977)	
049-1	Craven	Greatlake Drilling Great Lakes #2 1925	34-50-58 76-58-50	2351 (717)	-2288 (-697)	Granite (Piedmont)	Mansfield (1927)	
049-2	Craven	Carolina Petroleum C. Bryan #1 1947	34-50-55 76-57-54	2435 (742)	-2361 (-720)	Granite* (Piedmont)	Berry (1948)	
053-1	Currituck	E.F. Blair Twiford #1 1965	36-18-10 75-55-30	4553 (1388)	-4516 (-1376)	Foliated garneti- ferous biotite schist & muscovite- quartz schist (Piedmont)	Allen & Wilson (1966); Denison & others (1967)	K/AR date 253±5 my muscovite Denison & others (1967)
055-1	Dare	Standard Oil of N.J. Esso #1 Hatteras Light, 1946	35-15-00 75-31-45	10,044 (3061)	-9853 (-3003)	Sheared quartz monzonite (Piedmont)	Swain (1947) Spangler (1950) Coffee (1977)	
055-3	Dare	Socony-Mobil Oil State of North Caro- lina #1 (Mobil #1) 1965	35-59-48 75-51-48	5255 (1602)	-5165 (-1574)	Sheared granite gneiss (Piedmont)	Allen & Wilson (1966); Denison & others (1967)	Rb/SR dates-585±40 my whole rock 520±30 my muscovite 544±40 my isochron age Dennison & others (1967)
055-4	Dare	Socony-Mobil Oil State of North Caro- lina #2 (Mobil #2) 1965	35-27-18 75-35-00	8382 (2555)	-8372 (-2551)	Biotite diabase (Piedmont)	Denison & others (1967)	K/AR date-354±7 my biotite Denison & others (1967)
055-5	Dare	E.F. Blair Marshal Collins #1 (Blair #3), 1965	35-53-00 74-40-15	6295 (1919)	-6266 (-1910)	Carbonitized amphibolite (Piedmont)	Allen & Wilson (1966); Denison & others (1967)	K/AR date-384±8 my hornblende Denison & others (1967)
055-6	Dare	E.F. Blair West Va. Pulp & Paper #1 (Blair #4) 1965	35-51-50 75-55-30	5147 (1569)	-5119 (-1560)	Quartz diorite (Piedmont)	Allen & Wilson (1966)	
055-9	Dare	Cities Service Westvaco #1A 1971	35-39-36 75-46-40	6288 (1917)	-6112 (-1863)	Granodiorite (Piedmont)	Preliminary examination of cuttings from 6200-6230 feet	R/SR date-924±40 my whole rock P.M. Brown, USGS (pers. comm., 1977)
055-10	Dare	Cities Service Westvaco #2A 1971	35-51-48 75-51-04	5817 (1773)	-5409 (-1649)	Brecciated granite (Piedmont)	Preliminary examination of cuttings from 5730-5780 feet and core	Rb/SR date-681±25 my whole rock P.M. Brown, USGS (pers. comm., 1977)
055-14	Dare	Cities Service First Colony Farms #1 1974	35-48-19 75-47-48	5582 (1701)	-5530 (-1686)	Granite (Piedmont)	Preliminary examination of cuttings from 5530-5560 feet	

APPENDIX (North Carolina) (continued)

WELL NO.	COUNTY	WELL NAME, OPERATOR LANDOWNER YEAR COMPLETED	LATITUDE LONGITUDE	TOTAL DEPTH	BASEMENT ELEVATION	BASEMENT ROCK TYPE (Interpretation)	PRINCIPAL SOURCE OF DATA	REMARKS
055-15	Dare	Cities Service First Colony Farms #2A 1974	35-56-38 75-52-20	5260 (1603)	-5209 (-1588)	Granite (Piedmont)	Preliminary examination of cuttings from 5250-5260 feet	
065-A	Edgecombe	Snyder Pump & Well Co. Town of Tarboro 1899	35-53-42 77-32-30	349 (106)	-278 (-85)	Weathered schist(?)* (Piedmont)	Clark & others (1912)	
065-B	Edgecombe	Virginia Well & Machinery Co. Town of Pinetops 1925	35-47-18 77-38-30	446 (136)	-242 (-74)	Granite* (Piedmont)	Mundorff (1944)	
073-1	Gates	S.E. Cullinam Drilling Co., Weyerhaeuser #1 1971	36-26-00 76-30-00 (approx.)	2150 (655)	-2130(?) (-649)	Low-grade meta-rhyolite (Piedmont)	Thin section of cuttings from 2150 feet	Unfoliated, devitrified, porphyritic, metarhyolite, 1% sulfides
083-A	Halifax	Heater Well Co. Tillery School #1	36-14-42 77-29-51	325	-135	Slate(?)*	#74 Mundorff (1946)	
091-1	Hertford	Pam-Beau Drilling Co. Edgar Bazemore #1 1949	36-19-00 76-49-00 (approx.)	1278(?) (390?)	-1235(?) (-376?)	Calcareous quartz schist (Piedmont)	Thin section of cuttings from 1275 feet	Foliated-quartz 60%, epidote 20% with plagioclase, calcite, muscovite, biotite, opaques
093-A	Hoke	Heater Well Co. North Carolina Sanitorium #1 1954	35-03-30 79-19-00	401 (122)	+130 (+40)	Sericite chlorite schist (Piedmont)	Brown (1958)	
095-9	Hyde	Mobil Oil Corp. Mobil #3, Pamlico Sound 1965	35-18-25 75-49-45	7314 (2229)	-7236 (-2206)	Gneissic granite (Piedmont)	Allen & Wilson (1966) Dennison & others (1967)	Rb/SR date-590$\pm$30 my muscovite 610$\pm$60 my whole rock Dennison & others (1967)
103-1	Jones	Peter Henderson Peter Henderson Hoffman Forest #2 1960	34-56-15 77-24-30	1218 (371)	-1163 (-354)	Low-grade meta-sediment (Piedmont)	Thin section of cuttings	Faint foliation-quartz, feldspar, muscovite, biotite, lithic fragments
107-A	Lenoir	Layne-Atlantic Town of LaGrange 1952	35-18-06 77-01-48	404 (123)	-287 (-87)	Granite (Piedmont)	Brown (1958)	
129-1	New Hanover	North Carolina Oil & Gas, Fort Fisher #1 1966	35-58-25 77-55-10	1558 (475)	-1536 (-468)	Greenstone (Piedmont)	Preliminary examination of cuttings from 1550-1560 feet	
129-A	New Hanover	Clarendon Water Works City of Wilmington 1899	34-15-00 77-57-00 (approx.)	1330 (405)	-1100 (-335)	Granite (Piedmont)	Holmes (1900) Mundorff (1944)	
131-A	Northampton	O.L. Truby Seaboard School	36-28-57 77-26-30	265 (81)	-100 (-30)	Granite* (Piedmont)	#47 Mundorff (1946)	

WELL NO.	COUNTY	WELL NAME, OPERATOR LANDOWNER YEAR COMPLETED	LATITUDE LONGITUDE	TOTAL DEPTH	BASEMENT ELEVATION	BASEMENT ROCK TYPE (Interpretation)	PRINCIPAL SOURCE OF DATA	REMARKS
131-B	Northampton	Heater Well Co. State Prison Camp 112	36-24-12 77-26-12	296 (90)	-176 (-54)	Granite* (Piedmont)	#66 Mundorff (1946)	
133-1	Onslow	International Paper Cadco #1 1950	34-32-50 77-33-00	1497 (456)	-1392(?) (-424?)	Biotite gneiss with granitic vein (Piedmont)	Thin section of cuttings from 1494-1495 feet	Foliated-biotite 50%, quartz & feldspar 40%, epidote 10%, opaques 2%
133-4	Onslow	Bryant Seay Seay-Hoffman Forest #1 1959	34-54-00 77-23-45	1433 (437)	-1368 (-417)	Low-grade felsic metavolcanic rock (Piedmont)	Thin section of cuttings from 1395-1410 feet	
133-7	Onslow	Peter Henderson Peter Henderson Hoffman Forest #3 1960	34-49-30 77-23-55	1328 (405)		Low-grade intermediate metavolcanic rock (Piedmont)	Thin section of cuttings from 1310-1320 feet	Fine-grained, slight foliation-feldspar, quartz, epidote, biotite, muscovite, chlorite, opaques
133-12	Onslow	North Carolina Oil & Gas, International Paper #2 1967	34-39-40 77-28-55 (approx.)	1402 (427)		Low-grade metagraywacke (Piedmont)	Thin section of cuttings from 1390-1400 feet	Fine-grained, foliated-quartz, feldspar, muscovite, biotite & actinolite altering to chlorite, opaques
133-13	Onslow	North Carolina Oil & Gas, Baucom #1 1967	34-40-20 77-30-20	1414 (431)	-1355 (413)	Low-grade mafic metavolcanic rock (Piedmont)	Thin section of cuttings from 1410-1417 feet	Fine-grained, unfoliated-plagioclase, actinolite, epidote, chlorite, quartz, muscovite, calcite, opaques
133-14	Onslow	North Carolina Oil & Gas, Evan #1 1967	34-41-30 77-30-30	1370 (418)	-1367 (-417)	Diorite (Piedmont)	Thin section of cuttings from 1360-1370 feet	Unfoliated-plagioclase 60%, hornblende 20%, quartz 10%, biotite 5%, opaques 3%
137-1	Pamlico	Carolina Petroleum N.C. Pulpwood #1 1947	35-04-35 76-39-00 (approx.)	3667 (1118)	-3647 (-1112)	Granite* (Piedmont)	Berry (1948)	
137-2	Pamlico	Carolina Petroleum Atlas Plywood #1 1947	35-05-15 76-40-35	3425 (1044)	-3406 (-1038)	Granite* (Piedmont)	Berry (1948)	
139-1	Pasquotank	S.E. Cullinan Hoerner-Waldorf #1 1971	36-20-? 76-22-?	2715 (828)	≈2600 (≈792)	Basalt, diabase, serpentinite (Triassic?)	Thin section of cuttings from 2690-2700 feet	1-Fine-grained altered basalt, phenocrysts of plagioclase & clinopyroxene 2-Diabase-ophitic texture-augite 55%, plagioclase 40%, opaques 5% 3-Serpentinite fragments
147-A	Pitt	Layne-Atlantic Town of Farmville 1937	35-35-30 77-35-00 (approx.)	472 (144)	-385 (-117)	Granite* (Piedmont)	Mundorff (1944)	
155-A	Robeson	City of Lumberton ?		435 (133)		Slate (Piedmont)	Brown (1958)	

APPENDIX (North Carolina) (continued)

WELL NO.	COUNTY	WELL NAME, OPERATOR LANDOWNER YEAR COMPLETED	LATITUDE LONGITUDE	TOTAL DEPTH	BASEMENT ELEVATION	BASEMENT ROCK TYPE (Interpretation)	PRINCIPAL SOURCE OF DATA	REMARKS
163-A	Sampson	Layne-Atlantic Town of Roseboro 1955	34-57-30 78-30-30 (approx.)	420 (128)	-219 (-67)	Granite gneiss (Piedmont)	Brown (1958)	
163-B	Sampson	Heater Well Co. Henry Vann #1 1955	35-06-00 78-13-20	271 (83)	-79 (-24)	Schist (Piedmont)	Brown (1958)	
165-A	Scotland	Virginia Machinery & Well Co. US Army 1942	34-46-40 79-22-40 (approx.)	448 (137)	-155 (-47)	Gray-green schist (Piedmont)	Brown (1958)	
177-1	Tyrrell	Exchange Oil & Gas Westvaco #2 1971	35-53-33 76-09-35	4198 (1280)	-3883 (-1153)	Metagraywacke (Piedmont)	Thin section of cuttings from 4000-4010 & 4040-4050 feet	Fine-grained foliated matrix with coarser clasts of quartz 40%, microcline 20%, plagioclase 20%, polycrystalline clasts 20%; mild cataclastic texture
177-2	Tyrrell	Exchange Oil & Gas Westvaco #1 1971	35-47-56 76-12-20	4242 (1293)	-4064 (-1239)	Muscovite-biotite schist (Piedmont)	Thin section of cuttings from 4220-4230 feet	Fine-grained, strongly foliated-quartz 50%, muscovite 20%, biotite 10%, plagioclase 10%, chlorite 8%, magnetite 2%
191-A	Wayne	Layne-Atlantic City of Goldsboro 1950	35-23-15 77-59-40 (approx.)	133 (41)	-18 (-5)	Green schist (Piedmont)	Brown (1958)	
195-A	Wilson	Heater Well Co. Dr. A.B. Williams 1942	35-44-30 77-45-00	335 (102)	-177 (-54)	Green slates* (Piedmont)	Mundorff (1944)	
	Northhampton Halifax Nash Edgecombe Wilson	Many wells				Granite* ○ map symbol Schist and slate* □ map symbol	Mundorff (1946)	
	Johnston Sampson Wayne	Many wells				Slate * □ map symbol	Pusey (1960)	
	Lee Richmond Cumberland Harnett Moore	Many wells				Slate * □ map symbol Triassic* △ map symbol	Schipf (1961, 1964)	

APPENDIX (continued)

SOUTH CAROLINA

WELL NO.	COUNTY	WELL NAME, OPERATOR LANDOWNER YEAR COMPLETED	LATITUDE LONTITUDE	TOTAL DEPTH	BASEMENT ELEVATION	BASEMENT ROCK TYPE (Interpretation)	PRINCIPAL SOURCE OF DATA	REMARKS
1	Aiken	City of Aiken Before 1896	33-33-24 81-41-00	558 (170)	+67 (+20)	Granite* (Piedmont)	Darton (1896)	
2	Aiken	US Government	33-20-22 81-44-03	750 (229) (approx.)	-357 (-109)	Chlorite schist (Piedmont)	G.E. Siple (pers. comm., 1971) (Well #20M) Siple (1967)	
3	Aiken	US Government	33-15-00 81-48-15	765 (233)	-585 (-178)	Chlorite schist (Piedmont)	G.E. Siple (pers. comm., 1971) (Well #P4R) Christl (1964)	
4	Aiken	US Government 1961	33-17-48 81-40-16	1904 (580)	-615 (-187)	Quartz-feldspar gneiss (Piedmont)	(Well #1) Diment & others (1965)	
5	Aiken	US Government 1961	33-16-46 81-39-30	1982 (604)	-690 (-210)	Quartz-hornblende-chlorite schist & quartz-feldspar-chlorite-epidote gneiss (Piedmont)	(Well #2) Diment & others (1965)	
6	Aiken	US Government 1961	33-17-07 81-39-49	1942 (592)	-649 (-198)	Quartz-chlorite-epidote-biotite schist (Piedmont)	(Well #3) Diment & others (1965)	
7	Aiken	US Government 1961	33-16-35 81-40-10	1938 (591)	-673 (-205)	Quartz-sericite & quartz-chlorite-biotite schists (Piedmont)	(Well #4) Diment & others (1965)	
8	Aiken	US Government 1961	33-17-22 81-39-24	1838 (560)	-643 (-196)	Quartz-chlorite-epidote schist (Piedmont)	(Well #5) Diment & others (1965)	
9	Aiken	US Government 1961	33-17-14 81-39-05	1913 (583)	-671 (-205)	Quartz-chlorite-hornblende-epidote schist (Piedmont)	(Well #6) Diment & others (1965)	
10	Aiken	US Government 1961	33-17-05 81-38-59	1969 (600)	-682 (-208)	Quartz-chlorite-hornblende schist (Piedmont)	(Well #7) Diment & others (1965)	
11	Barnwell	US Government	33-16-36 81-38-26	1968 (600) (approx.)	-590(?) (-180) (approx.)	Hornblende schist & gneiss (Piedmont)	(Well #DRB 8) Marine & Siple (1974)	

APPENDIX (South Carolina) (continued)

WELL NO.	COUNTY	WELL NAME, OPERATOR LANDOWNER YEAR COMPLETED	LATITUDE LONGITUDE	TOTAL DEPTH	BASEMENT ELEVATION	BASEMENT ROCK TYPE (Interpretation)	PRINCIPAL SOURCE OF DATA	REMARKS
12	Barnwell	US Government 1969	33-14-54 81-36-43	2694 (821)	-722 (-220) (approx.)	Red fanglomerate (1593 feet) (Triassic)	(Well #DRB 9) Marine & Siple (1974)	
					-2333 (-711)	Augen gneiss (Piedmont)		
13	Barnwell	US Government 1971	33-12-18 81-34-24	4206 (1282)	-919 (-280)	Red mudstone, sandstone, conglomerate (Triassic)	(Well #DRB 10) Marine & Siple (1974)	
14	Barnwell	US Government	33-13-48 81-35-49	3320 (1012)	-820(?) (-250) (approx.)	Red mudstone & sandstone (Triassic)	(Well #DRB 11) Marine (1974)	
15	Barnwell	US Government 1962	33-09-05 81-35-39	1313 (400)	-1044 (-318)	Red siltstone & sandstone (Triassic)	(Well #P5R) Christl (1964) Siple (1967)	
16	Barnwell	US Government	33-14-12 81-36-15	1272(?) (388)	-810(?) (-247) (approx.)	Red mudstone (Triassic)	(Well #P12R) Marine (1974)	
17	Darlington	Layne-Atlantic City of Hartsville	34-23-00 80-05-00 (approx.)	432 (132)	-258 (-79)	Schist (Piedmont)	(Well #9) Siple (1958)	
18	Dillon	Carolina Drilling & Equipment Co. City of Dillon	34-25-00 79-22-30 (approx.)	595 (181)	-480 (-146)	Rhyolite breccia (Piedmont)	(Well #10) Siple (1958)	
19	Dorchester	Sun Oil Co.(?) Mabeleanor #1(?)	35-01-00 80-10-42	2470 (753)	-2379 (-725)	Diabase & red shale (Triassic)	Unpublished well log in files of USGS (1940)	
20	Dorchester	US Army Corps of Engineers USGS #1 1975	34-53-12 80-21-42	2599 (792)	-2440 (-744)	Amygdaloidal basalt (Triassic)	Gohn & others (1976)	
21	Florence	Carolina Drilling & Equipment Co. City of Florence	34-11-20 79-45-20 (approx.)	715 (218)	-602 (-183)	Olivine diabase (Triassic)	(Well #11) Siple (1958)	
22	Marion	City of Marion Before 1896	79-22-50 34-11-00 (approx.)	1244 (379)	-632 (-193)	Crystalline rock* (Piedmont)	Darton (1896) Siple (1958)	
23	Sumter	Layne-Atlantic City of Sumter 1952	33-56-50 80-20-00 (approx.)	784 (239)	-620 (-189)	Granite* (Piedmont)	(Well #19) Siple (1958)	

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(Well descriptions largely from Coffee (1977) in North Carolina, and Marsalis (1970) in Georgia. Basement rock type from references cited in Table.)

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