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INDICATORS OF GROUND WATER QUALITY AND YIELD FOR A PUBLIC WATER SUPPLY IN ROCK FRACTURE ZONES OF THE PIEDMONT

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Clemson University
Clemson, South Carolina 29631

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ABSTRACT

This investigation dealt with field and laboratory studies on indicators of ground water quality and well yields from a variety of igneous, metamorphic, and fault rocks situated in the Piedmont of South Carolina. The principal study area was Greenwood County, which is occupied by the Carolina Slate, Charlotte, and Kings Mountain Belts of metamorphic rocks, and several large plutons. Magnetometer profiles were made on three basic dikes including the Easley Dolerite of Pickens County, the Due West Dolerite of Abbeville County, and the Shoals Junction Dolerite of Greenwood County. A magnetic profile was made also on a large, massive, igneous intrusive, the Greenwood Pluton. In addition, a portion of the Mesozoic Pax Mountain Fault was investigated because it is one of the largest and most conspicuous lineaments in the Piedmont, and because data from seven recently drilled wells disclosed some very interesting hydrological problems.

More than 150 lineaments and fracture traces were mapped in Greenwood County. These features were mapped from studies of aerial photographs, satellite imagery, and topographic maps. Field studies show that most of these features were caused by steeply dipping or vertical faults and joints. Other linear features were associated with fold axes or dolerite dikes.

While there are numerous occurrences of fault rock float fragments in Greenwood County, good, continuous outcrops of fault rocks are not as common in this county as they are in Abbeville County, which is on its western border. Nevertheless, we have made some tentative interpretations regarding the extensions of the major faults of Abbeville County

into Greenwood. The Lowndesville Belt can be traced eastward from the county line for a mile or so into Greenwood County. Perhaps it extends N65°E across the county into adjacent Laurens County, but this interpretation is speculative because of poor outcrop control. The Cold Springs Shear and the Watts Zones appear to merge a few miles east of the county line, and scattered fragments of mylonite float trend N60°E toward an excellent outcrop of mylonite which occurs within the Mulberry Creek Granite. This mylonitic zone, which has a length of 3 miles, has been traced to the Laurens County - Greenwood County line.

The yields of 206 wells drilled in Greenwood County were obtained. The yields varied from 0 to 150 gpm, while the median was 17 gpm. The median yield of the wells situated in fracture traces and lineaments was 25 gpm, which was about twice the median yield of 12 gpm of the randomly located wells.

The median productivity of the wells situated in the Carolina Slate Belt was 28 gpm, while the median yields of the Charlotte and Kings Mountain belts were 17 gpm and 15 gpm respectively. In addition, the median productivity of the Carolina Slate was higher than the median yields of the Mulberry Creek Granite, the Coronaca Granite-Syenite and the Greenwood Pluton, which were respectively 22 gpm, 15 gpm, and 17 gpm. We feel that the higher productivity of the Carolina Slate Belt is caused by a greater abundance of permeable openings in the slate belt rocks. These openings include numerous bedding planes within the laminated argillite, compositional bedding planes between the argillites and volcaniclastic beds, and numerous oblique and vertically dipping joints. The higher incidence of planar openings in the rocks of the Carolina Slate Belt causes these rocks to be more poorly consolidated than the rocks of the other Piedmont metamorphic belts and the igneous rocks also. More than half of the Carolina Slate Belt wells had casing depths which exceeded 100 feet and 36 percent had casing depths of more than 190 feet.

One hundred and eleven ground water samples were analyzed for hardness, alkalinity, pH, Cl, Mn, Zn, and Cu. In addition, 59 specimens were analyzed for total dissolved solids, 70 Ca determinations were made, and 18 Mg analyses were reported. The values of the chemical parameters of most of the samples were good to excellent with the exceptions of pH, Fe and Mn. With regard to water quality, the principal problem was low pH. The median value was 6.4, and 25 percent of the samples had pH values below 6.0. The lowest median pH, 5.8, was reported from 9 wells drilled in the Coronaca Granite-Syenite. A problem of secondary importance was excessive concentrations of iron in 14 percent of the samples and excess manganese in 10 percent of the samples.

Two new dolerite dikes were mapped. The first dike, the Shoals Junction Dolerite, begins in northern Greenwood County, and trends N40°W into Abbeville County, a distance of 5 miles. The second one, the Due West Dolerite, is situated about 10 miles SSE of Due West in Abbeville County. Its length is 2.5 miles, while its strike is N34°W. Both dikes dip vertically or nearly so. Magnetometer profiles were made across these two dikes, and on the Easley Dolerite of Pickens County. Studies of these profiles and field mapping suggest that the Shoals Junction Dolerite consists of multiple dikes instead of a single tabular pluton. These multiple dikes were emplaced in extensional fractures which cut across Paleozoic granitic rocks and metamorphic rocks of the Kings Mountain Belt. Unfortunately, no drilled wells were located in the Shoals Junction Dolerite and thus, its ground water capability is not known. Nevertheless, because of the high incidence of fractures here, this zone might well contain good supplies of ground water.

Our studies of the data from 7 recently drilled wells situated along the Pax Mountain Fault Zone in northern Greenville County, disclosed some interesting and complex problems. One of the wells situated along the axis of this ridge was drilled to a depth of 390 feet. X-ray diffraction studies of the well cuttings showed that this well penetrated poorly consolidated fault breccia and clay gouge to a depth of 330 feet. This is the deepest occurrence of poorly consolidated rocks known in the Piedmont. Five wells were abandoned here and only two were productive. Three of the wells had to be abandoned because they caved in at a depth of about 260 feet, just when they had encountered prolific amounts of water. Two of the wells were dry holes because the clay gouge had clogged up the void spaces between the coarse breccia particles. The foregoing findings indicate the need for the application of seismic and resistivity studies on fault zones in order to minimize the incidence of expensive nonproductive wells. Seismic methods can be utilized to determine the degree of consolidation of the fractured rocks, while resistivity methods can be used to detect the presence or absence of ground water.

INTRODUCTION

Location of area and objectives. This investigation deals with indicators of ground water quality and well yields from various igneous, metamorphic, and fault rocks. Most of the wells with good to excellent yields that occur in the Piedmont are associated with natural linear features called lineaments and fracture traces. They are termed lineaments if they exceed 1.5 km in length, and fracture traces if their length is less than 1.5 km. These features are caused mainly by steeply dipping faults or joints, and by fold axes. They form vegetative or soil tonal alignments that are expressed on aerial photographs and satellite imagery. In addition, many of the more obvious ones can be detected on topographic maps by the analysis of contour lines or stream drainage patterns.

The principal study area, Greenwood County, is shown in figure 1. In addition, three linear features situated in three other Piedmont counties are also shown in figure 1. These features include the Pax Mountain Fault Zone of Greenville County, the Easley Dolerite of Pickens County, and the Due West Dolerite of Abbeville County. A fourth lineament selected for detailed study was the Shoals Junction Dolerite of Greenwood County.

Greenwood County was selected for this study because it contains three different metamorphic rock assemblages termed the Carolina Slate Belt, the Charlotte Belt, and the Kings Mountain Belt by Overstreet and Bell (1965b). Moreover, it contains a variety of igneous plutons that yield ground water supplies which were expected to have distinctively different chemical properties. These igneous bodies include the Mulberry Creek Granite, the Coronaca Granite-Syenite, and the Greenwood Pluton which consists of gabbro and dolerite.

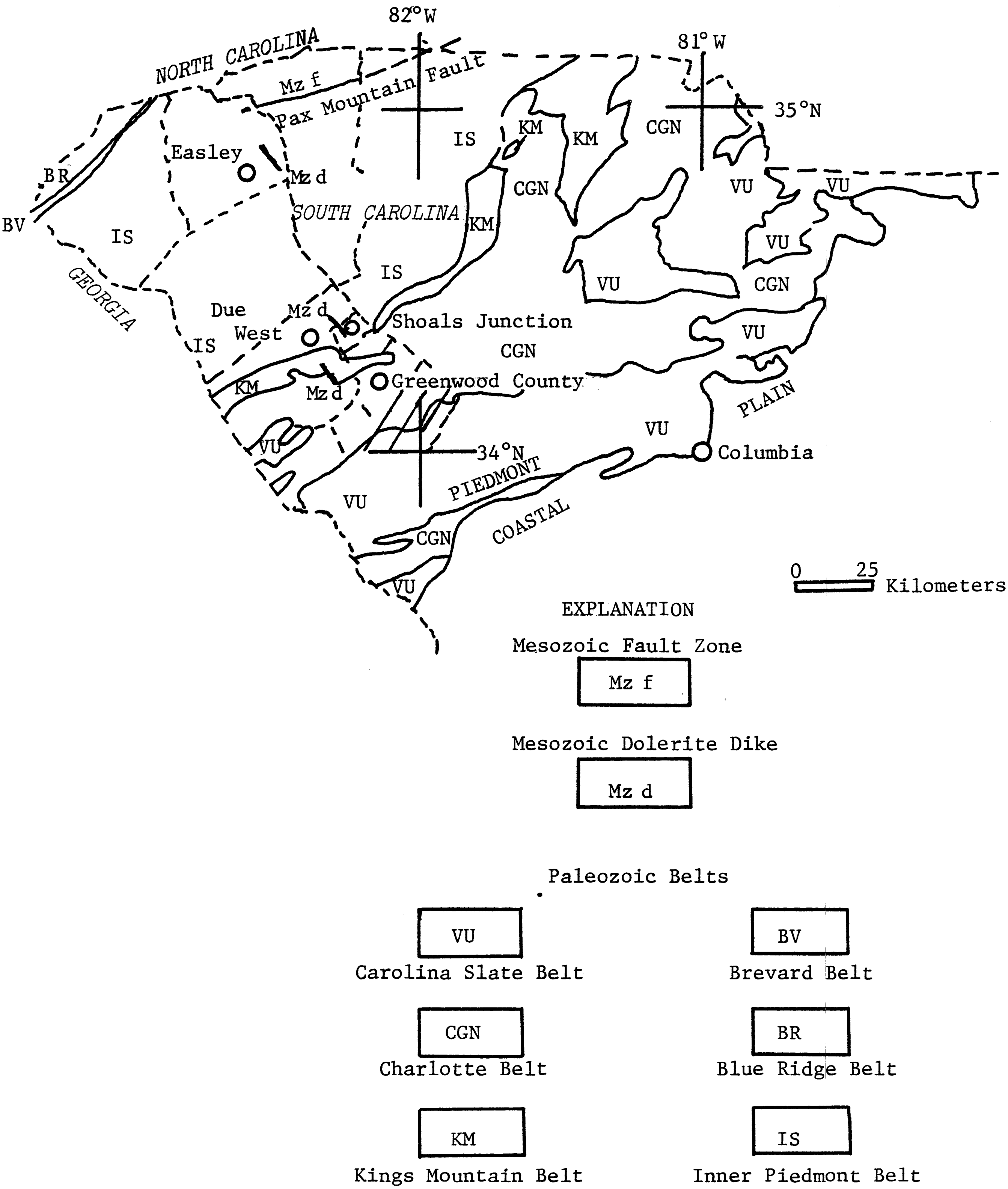

Figure 1. Index map showing the principal study area, Greenwood County, and four lineaments selected for this investigation including the Pax Mountain Fault, and the Easley, Shoals Junction, and Due West Dolerites. The geologic belts of the Piedmont are from Overstreet and Bell (1965a) and Griffin (1978).

More than 60 dolerite dikes are shown on the geologic map of the South Carolina Piedmont of Overstreet and Bell (1965b). In addition, there are probably several dozen other dikes which have not been reported previously. Because these doleritic plutons contain numerous vertical orthogonal joints as well as oblique joint sets, they offer an excellent opportunity for ground water exploration. Nonetheless, heretofore no ground water investigations on these dolerite dikes have been reported. In the present study, we discovered and mapped two new Mesozoic dolerite dikes, the Shoals Junction and Due West Dolerites. In addition, we attempted to obtain water well data regarding the above dikes. Magnetometer traverses were run on three dikes including the aforementioned two intrusives, and the Easley Dolerite of Snipes and Furr (1979). The study of these three Piedmont Mesozoic dolerite dikes merely marks a beginning, but because of time constraints we were not able to study additional ones.

More than 70 linear fault zones occupied by a variety of different fault rocks have been reported from the Upper Piedmont of South Carolina (Conley and Drummond, 1965; Birkhead, 1973; Price, 1969; Griffin, 1978, 1979; Snipes et al., 1979; Snipes, 1981; Snipes et al., 1983). Snipes and his coinvestigators (1981, 1983) have presented some well yield data on some of these fault zones, but, for the most part, detailed data on well yields and water quality are scarce. In the present investigation, we selected one of these faults, the Pax Mountain Fault Zone, for special study for the following reasons:

1. It is the most conspicuous and longest Mesozoic fault in the South Carolina Piedmont.

2. It contains a variety of fault rocks including silicified breccia, fault breccia, and gouge.

3. It poses some interesting problems in geohydrology and some difficult well drilling problems.

4. Data on seven wells recently drilled in this fault zone were available.

Many of the water wells drilled in the Piedmont have low productivities or they are dry holes. This is caused by the fact that the igneous and metamorphic rocks are virtually impermeable except in fracture zones where their permeability is much higher. Because many of the geologic features such as joints, faults, and axial planes dip vertically or nearly so, they are expressed as lineaments or fracture traces on aerial photographs and topographic maps. Our research in Oconee, Pickens, Anderson, and Abbeville Counties (Snipes, 1981; Snipes et al., 1983) showed that the median yield of water wells situated in fracture zones was about four times greater than the median of wells which had been randomly located. In addition, all of the wells which produce 100 gallons per minute or more were situated in fracture zones. The writers, as well as other geologists, have mapped these linear features in the laboratory and in the field in order to assist water well drillers and their clients in obtaining good supplies of ground water. Despite the fact that a great number of successful wells have been drilled utilizing fracture trace mapping, this method sometimes fails because of several geologic problems:

1. Some of the fault zones are occupied by unconsolidated rocks and such wells usually cave in just when they encounter large amounts of water.

2. Some of the fault zones contain clay gouge which makes the water too muddy to drink or in some cases clogs up the void spaces between the coarse particles.
3. Some of the joints and faults have been filled with secondary quartz, thus causing dry holes.
4. At some of the well sites where the rocks contain open joints, the ground water has migrated downdip away from the well sites.
5. In some of the jointed basic igneous rocks, the ground water quality has been impaired by the presence of too much dissolved solids or by having a hardness which was too great.
6. In many of the ground water samples taken from wells drilled in light colored igneous and metamorphic rocks, the pH was too low, thereby causing excessive corrosiveness.

The objectives of this research were:

1. To study the water quality and well yield data for different assemblages of metamorphic rocks from the Carolina Slate Belt, and the Charlotte and Kings Mountain Belts of Greenwood County.
2. To study the water quality and well yields from different plutonic rocks, such as granite, syenite, diorite, gabbro, and dolerite in order to determine if the ground water from these rocks had distinctively different chemical properties, and if the well yields varied significantly.
3. To make some preliminary magnetometer studies in order to determine the feasibility of utilizing the magnetometer in geohydrological investigations of basic igneous intrusives.

4. To map the Mesozoic fault zones of Greenwood County on a reconnaissance basis, to determine the water quality and well yields of the drilled wells situated within the fault zones, and to make a more detailed hydrological investigation of the Pax Mountain Fault of northern Greenville County.

Previous investigations. No previous ground water research has been reported on the study area, Greenwood County, but reconnaissance geologic mapping has been reported by Overstreet and Bell (1965a), and a gravimetric survey was published by Chalcraft (1981). The petrology of the Greenwood Pluton was investigated by Chalcraft (1978). In addition, a petrologic study of the northern part of Greenwood County was reported by McSween (1970).

Overstreet and Bell (1965a) mapped igneous and metamorphic rocks in the Piedmont of South Carolina and subdivided a portion of this metamorphic terrain into the Kings Mountain, Charlotte, and Carolina Slate Belts. Further investigations by McSween (1970) and Chalcraft (1981) show that four large plutons were emplaced in the metamorphic rocks (fig. 2, in pocket).

In Greenwood County, the Kings Mountain Belt consists of fine-grained mica schist, hornblende schist, biotite and hornblende gneisses, and minor amounts of quartzite and marble (Overstreet and Bell, 1965b). The Charlotte Belt consists of granite gneiss, biotite gneiss, muscovite schist, amphibolite, diorite gneiss, granite and granodiorite (Chalcraft, 1981). The Carolina Slate Belt is composed of laminated argillite, phyllite, metavolcanic rocks, and minor amounts of volcaniclastic sandstone (Chalcraft, 1981).

The Greenwood Pluton cuts across the contact between the Charlotte Belt and the Carolina Slate Belt, while the Verdery Gabbro and the Coronaca Granite-Syenite occur within the Charlotte Belt. The Mulberry Creek Granite intrudes the metamorphic rocks of the Kings Mountain Belt.

Northeast trending felsite and porphyritic felsite intrude the Carolina Slate Belt as well as gneisses of the Charlotte Belt (Ritchie and Fallaw, 1978). A few dolerite dikes occur near the contact with the Greenwood Pluton (Chalcraft, 1981).

While no ground water investigation on the study area has been published, ground water surveys have been reported in the nearby Piedmont Counties of Greenville (Koch, 1968), Pickens (Johnson et al., 1968), Spartanburg (Bloxham et al., 1970), Oconee and Anderson (Snipes 1981), and Abbeville (Snipes et al., 1983).

In the report of Johnson et al. (1968), the capability of fracture zones to yield large quantities of ground water in contrast to the otherwise impermeable igneous and metamorphic rocks was pointed out, but the zones of fracture were not mapped. In the studies of Snipes (1980, 1981) on Anderson and Oconee Counties, and a portion of Pickens County, 400 linear fracture zones were mapped; 43 of them were fault zones, while the remainder were attributed to systematic joints. Two hundred water well locations were plotted. The most productive wells were situated in fracture zones and their yields ranged from 10 gallons per minute to 500 gallons per minute with a median yield of 30 gallons per minute. In contrast, most of the wells which were not situated in fracture zones produced less than 10 gallons per minute or were nonproductive.

In the Abbeville County study of Snipes et al. (1983), more than 200 lineaments and fracture traces were mapped. Drilled water wells situated in lineaments had a median productivity of 35 gallons per minute and the wells situated in fracture traces had a median yield of 25 gallons per minute. The largest yield reported from both lineaments and fracture traces was 300 gallons per minute. In contrast, the median yield of the unoriented features, that is, wells situated in coherent metamorphic and igneous rocks which were not fractured, was 5 gallons per minute and the largest yield was 30 gallons per minute.

The foregoing studies on the relationship of well productivities to fracture traces and lineaments are in accord with earlier investigations by Parizek (1976) in Pennsylvania. His studies demonstrated that (1) wells situated in linear features have a greater probability of being good producers than dry holes, (2) the median productivities of such wells is three to four times greater than randomly located ones, and (3) in metamorphic and igneous rocks, fracture zones offer the best chance of obtaining maximum well yields at the least economic risk.

The studies of LeGrand (1949, 1954, and 1979) on sheeting joints in granites in Georgia, ground water in metamorphic rocks in the Statesville area, North Carolina, and on hydrological evaluation techniques of fractured rocks, have also documented the capabilities of fractured rocks to yield large volumes of water in contrast to the otherwise almost impermeable metamorphic and igneous rocks.

With regard to water quality, the investigation of Snipes (1981) in Oconee, Anderson, and Pickens Counties reveals that 44% (11 of 25) of the hand dug wells were contaminated with coliform bacteria. In the Abbeville

County study of Snipes et al. (1983), six out of seven bored and hand dug wells were contaminated with fecal bacteria. In contrast to the high incidence of bacterial contamination which occurs in the water of the hand dug and bored wells, no fecal bacteria have been observed in water samples from six drilled wells in Abbeville County and eleven drilled ones from Oconee, Anderson and Pickens Counties.

Published studies of the chemical analyses of water well samples from the counties of Pickens (Johnson et al., 1968), Spartanburg (Bloxham et al., 1970), Oconee and Anderson (Snipes, 1981), and Abbeville County (Snipes et al., 1983) show that the chemical characteristics of the ground water of the northern Piedmont of South Carolina are good to excellent. The content of total dissolved solids, and the hardness, as well as the concentrations of the major elements and most of the minor elements, are low in most samples. Notwithstanding the foregoing favorable chemical characteristics, the pH values are low with the medians varying from 6.2 in Oconee, Anderson, and Pickens Counties, to 6.6 in Abbeville County. Thus, the water from many of the wells in this portion of the Piedmont is mildly to moderately corrosive. In addition, approximately 5% of the wells have iron concentrations of greater than 0.3 mg/1, the limit recommended by SC DHEC. Moreover, about 1% of the water samples exceed the recommended limit of 1.0 mg/1 for copper.

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HYDROLOGIC CHARACTERISTICS OF THE METAMORPHIC BELTS AND PLUTONIC ROCKS OF GREENWOOD COUNTY

Introduction. This section deals with the hydrologic characteristics of the Kings Mountain, Charlotte, and Carolina Slate Belts, and the major plutons of Greenwood County. Specific topics include: (a) field and laboratory procedures, (b) hydrological characteristics of the regolith, (c) data on water wells, (d) relation of well yield to depth, (e) the productivities of wells according to rock types, and (f) the relation of topography, fracture traces and lineaments to well yields. The yields of 206 drilled wells were obtained mainly from well drillers' logs and plotted, and more than 150 fracture zones were mapped (fig. 2).

Methods. The laboratory and field procedures included:

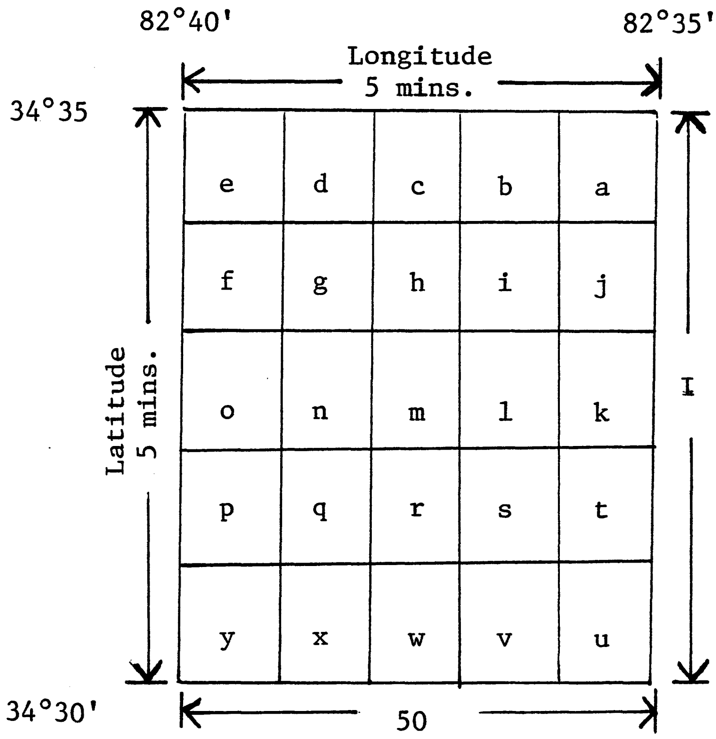
1. Reconnaissance analyses of photographs obtained from remote sensing devices, aerial photographs, and topographic maps in

order to locate prominent linear features which are potential fracture zones. Examples of photographs from remote sensing devices included those of the Apollo 9 satellite and the Skylab satellite. More detailed studies involved the utilization of black and white contact print aerial photographs at a scale of 1 inch equals 1,667 feet. The techniques of Lattman (1958), Trainer (1967), and Wobber (1967) were employed in locating potential fracture zones on the aerial photographs.

2. Detailed field mapping in order to determine if the above linear features were, in fact, fracture zones. This field mapping was done on topographic maps on a scale of 1:24,000 or in some instances on aerial photographs on a scale of 1:20,000. The dips and strikes of the fractures (joints and faults) were measured with a Brunton compass. The above field data were then compiled in as much detail as possible on county maps on a scale of 1 inch equals 2 miles in order to obtain the regional picture.

3. Location of wells. The system of the South Carolina Water Resources Commission (Spigner, 1979, personal communication) was utilized in plotting the wells on the maps and in all of the tables herein which pertain to well sites. A description of this system is given in figure 3.

4. Water well production data were obtained from drilling companies in the region in order to relate the yields of the wells to the fracture zones, assess the ground water capabilities of the region, and assist the potential user in predicting the loca-



<u>Meaning of number and letter designations</u>

Site Number 50-I-c-4

50 Locates well between 82°35' and 82°40'W longitude.

I Locates well between 34°30' and 34°35'N latitude.

c Sector c places well between 82°37' and 82°38'W longitude, and 34°34' and 34°35'W latitude.

4 Fourth well in sector c (the precise well locations in a sector are available from the authors upon request).

Figure 3. Explanation of the number and letter designations utilized in determining well locations. After Snipes *et al.*, 1983.

tions of high yield wells. Most of the available well production data were based upon the blowing well method. According to B. M. Hughes, President of Hughes Well Drilling Company, where pumping tests and blowing well measurements were made on the same well, the latter measurements tended to be too low, especially for wells where the yield exceeded 100 gpm.

Hydrological characteristics of the regolith. The regolith consists of the layer of decomposed rocks and disintegrated rock fragments, just above the hard bedrock. It includes the residual soil which occurs above the metamorphic and igneous rocks, and the alluvium which occupies flood plains within stream valleys. According to Bloxham *et al*. (1970), the regolith of the Piedmont acts as a storage reservoir to receive and absorb precipitation, which is subsequently released as recharge to fractures in the underlying rocks. It provides a more stable yield to wells and tends to lessen the incidence of extremely high and low water storage caused by alternate periods of abundant rainfall and drought. Furthermore, it decreases the amount of rainfall lost by overland runoff which occurs where bare bedrock is exposed.

In ground water studies on the Piedmont, estimates on the thickness of the regolith usually are based on the depth of casing in the drilled wells. Surface casing generally is set to a depth of about one foot in the bedrock just below the contact between it and the overlying regolith. Snipes (1981) found that the median thickness of the regolith was 50 feet in Oconee, Pickens, and Anderson Counties, and the maximum thickness reported was 150 feet. In Abbeville County, the median thickness was 67 feet while the maximum was 127 feet (Snipes *et al*., 1983). In contrast, the median depth of casing and the maximum depth was considerably greater for 65 Greenwood County wells, being respectively 85 feet and 217 feet. We feel that this increase is caused largely by lithologic variations. In the northern counties of Oconee, Pickens, and Anderson, the dominant metamorphic rocks are gneisses and mica schists of the Inner Piedmont, while the main igneous ones are granitic in composition. Less cohesive metamorphic rocks, like slates, have not been reported. In addition, mafic plutons do not occupy much area. In contrast, there is a wider variety of metamorphic and plutonic rocks in Greenwood County. Moreover, compositional bedding planes are more abundant in the Greenwood County metamorphic rocks. In table 1, the percentages of wells in various metamorphic belts and plutonic rocks with depths of casing that are greater than 100 feet and 190 feet are tabulated. The wells situated in the softer, less cohesive, Carolina Slate Belt rocks have the greatest number of wells with casing depths that are greater than 100 feet and 190 feet, respectively. Fifty-seven percent of 14 Carolina Slate Belt wells have casing depths of greater than 100 feet, and 36% have depths of greater than 190 feet. Twenty-four percent of the Charlotte Belt wells have casing depths which are greater than 100 feet, and 17% of the Kings Mountain Belt wells have casing depths of greater than 100 feet, and only one well situated in the Kings Mountain Belt has a casing depth that exceeds 190 feet. Moreover, this well is situated in fault rocks consisting of quartz mylonite and biotite phyllonite. No wells situated in the Coronaca Granite-Syenite or the Mulberry Creek Granite have casing depths that exceed 100 feet. Thus, the more granitic rocks of

Table 1. Percentage of wells in various metamorphic belts and plutonic rocks with depths of casing ≥ 100 feet and ≥ 190 feet.

Metamorphic Belt or Intrusive	Number of wells with depth of casing reported	Number of wells with casing depths ≥ 100 ft	Percentage of wells with casing depths ≥ 100 ft	Number of wells with casing depths ≥ 190 ft	Percentage of wells with casing depths ≥ 190 ft
Carolina Slate Belt	14	8	57	5	36
Charlotte Belt	21	5	24	0	0
Kings Mountain Belt	23	4	17	1*	4
Greenwood Pluton	2	1	50	0	0
Coronaca Granite-Syenite	3	0	0	0	0
Mulberry Creek Granite	2	0	0	0	0

* This well is situated in fault rocks consisting of quartz mylonite and biotite-phyllonite within the Kings Mountain Belt.

Greenwood County, like the ones of the northern Piedmont, are more resistant to chemical weathering than the other rock types.

In our previous studies (Snipes, 1981; Snipes *et al*., 1983), we have not found a relationship between well yields and the thicknesses of the regolith (depths of casing). In figure 4, the yields of 65 Greenwood County wells and regolith thicknesses are plotted. The data points are quite scattered, some of the wells with thick regoliths have low yields, while some with thin regoliths have high productivities. Thus, the Greenwood County results are in agreement with our previous findings. These results do not support the earlier suggestion of Johnson *et al*. (1968) that the greater the thickness of the residual soil the greater the well productivity.

Well data. The results of inventories of 206 Greenwood County drilled wells are given in Table A1. The well yields varied from 0 to 150 gpm, with a median yield of 17 gpm. In the succeeding sections the influence of well depth, rock type, topography and linear geologic features on well productivities is assessed.

Relation of well yield to depth of well. The well productivities with respect to well depths are plotted in figure 5. Notwithstanding the fact that the data points show considerable scatter, there is a tendency toward higher productivities at shallower depths and lower yields at greater depths. For example, all of the wells which produce 100 gpm or more occur at depths of less than 400 feet. Furthermore, no wells with depths of more than 400 feet have yields of 50 gpm or more.

In table 2 the depth intervals, median and mean yields, and mean yields in gpm/ft of the Greenwood County wells are listed. While there are some exceptions, notably at the depth interval of 350 - 399 feet

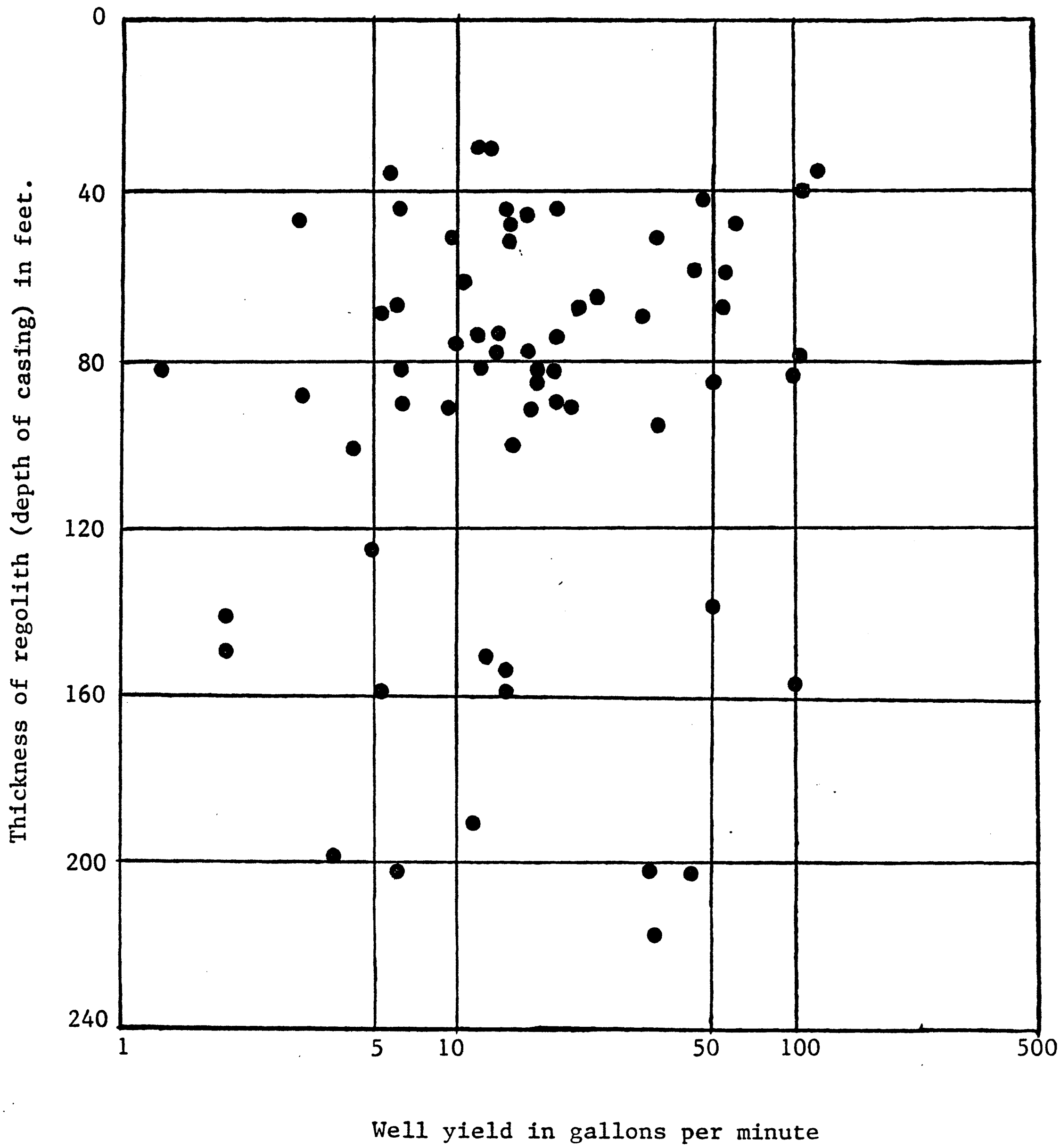


Figure 4. Relation of well yield to thickness of regolith in Greenwood County, SC.

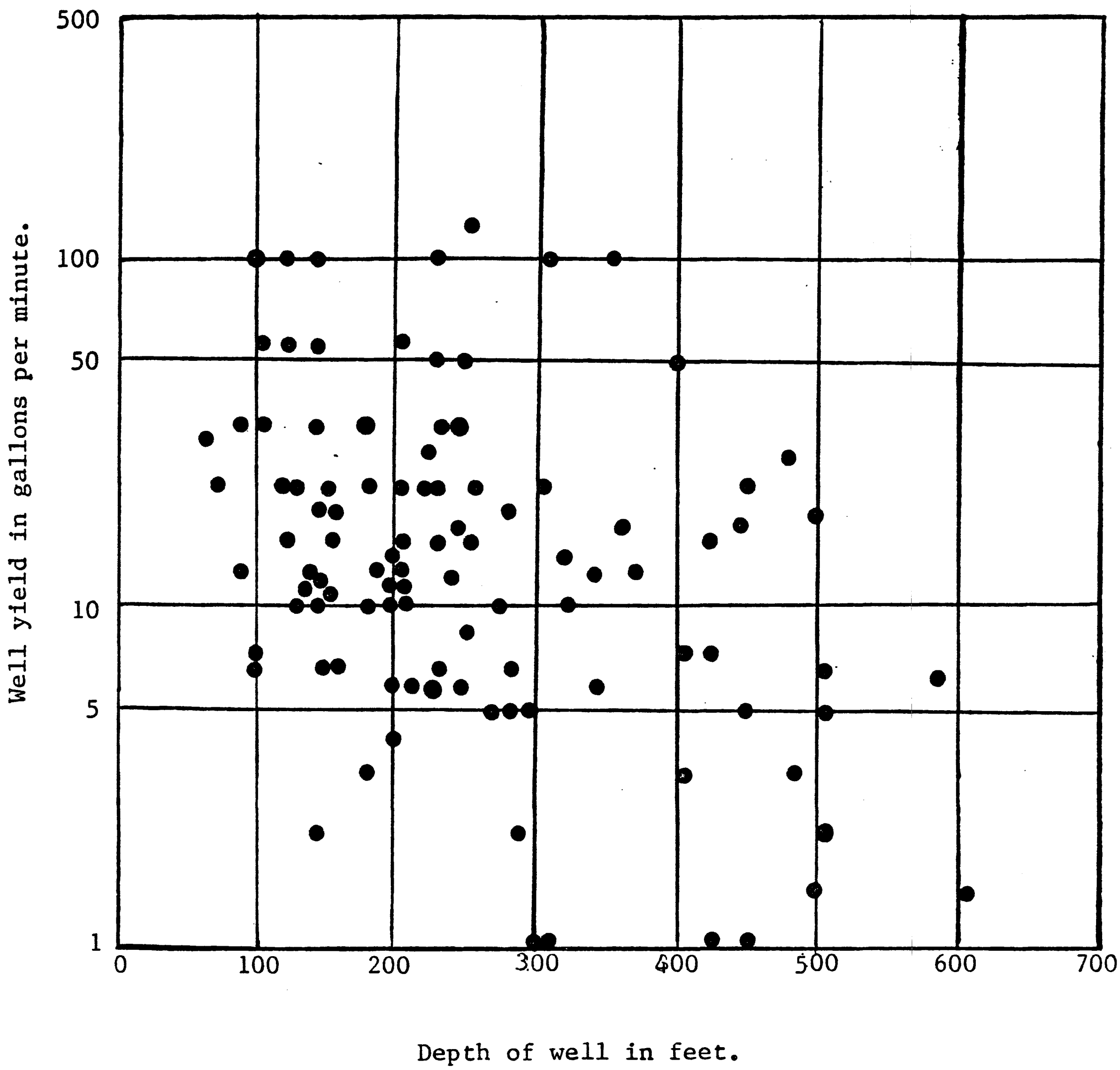


Figure 5. Relation of well yield to depth of well.

Table 2. Relation of well yield to depth*.

Number of Wells	Depth Interval feet	Median Yield gpm	Mean Yield gpm	Mean Yield gpm/ft
4	50 - 99	34.0	30.75	0.41
24	100 - 149	27.5	35.3	0.28
12	150 - 199	13.0	17.2	0.10
27	200 - 249	17.0	23.6	0.10
11	250 - 299	10.0	28.5	0.10
13	300 - 349	5.0	14.1	0.04
3	350 - 399	22.0	45.7	0.12
14	400 - 499	6.5	13.4	0.03
7	500 - 700	5.0	7.3	0.01

*Well depth data were available on 115 wells.

where only three wells are reported, there is a tendency toward a decline in the median and mean yields with depth. In this regard, perhaps the most significant parameter is the mean yield in gpm/ft. At shallower depths, i.e., less than 150 feet, the mean yield in gpm/ft is 3 to 4 times (0.28 - 0.41 gpm/ft) greater than it is in the intermediate depth interval of 150 - 300 feet, where the mean yield in gpm/ft is only 0.03 to 0.01. We feel that this decrease in the yield in gpm/ft with depth is caused by several factors including: (1) a decrease in the incidence of sheeting joints at depths which exceed 150 feet, (2) a decrease in the incidence of steeply dipping extension joints at depths of 400 feet or more, (3) a decrease in the width of the openings associated with bedding planes, joints and faults caused by increased pressure due to compaction, and (4) a tendency toward a decrease in the amount of chemical weathering with depth. With regard to the last factor there are several notable exceptions, especially within highly brecciated fault zones usch as the Pax Mountain Fault, where chemical weathering has occurred at depths of as much as 350 feet. This fault will be discussed in a later section.

Influence of rock type on well yields. Three Paleozoic metamorphic belts occur within Greenwood County (Overstreet and Bell, 1965a, 1965b), and four large igneous intrusives are exposed within this county (McSween, 1970; Chalcraft, 1981). These metamorphic belts and plutonic rocks are shown in figure 2.

The Kings Mountain Belt consists of fine-grained mica schist, hornblende schist, biotite and hornblende gneisses, and minor amounts of quartzite and marble (Overstreet and Bell, 1965). The Charlotte Belt consists of granite gneiss, biotite gneiss, muscovite schist, amphibolite, diorite gneiss, granite and granodiorite (Chalcraft, 1981). The Carolina Slate Belt is composed of laminated argillite, phyllite, metavolcanic rocks, and minor amounts of volcaniclastic sandstone (Chalcraft, 1981).

The Greenwood Pluton, which consists of gabbro and diorite, cuts across the contact between the Charlotte Belt and the Carolina Slate Belt. The Verdery Gabbro and the Coronaca Granite-Syenite occur within the Charlotte Belt, while the Mulberry Creek Granite intrudes the metamorphic rocks of the Kings Mountain Belt.

The yields of 206 wells from various metamorphic belts and plutonic rocks are listed in table 3. The median yield of 22 wells drilled in the Carolina Slate Belt was 28 gpm, which was 1.6 times greater than the median for all wells. We feel that this higher productivity is caused by several factors which have been observed during the course of the present investigation. These factors include: (1) the occurrence of numerous planar openings in the laminated argillite, (2) the presence of compositional bedding planes between the argillites, phyllites, and volcaniclastic sandstones, and (3) the fact that joints are abundant in most of the places where slate belt rocks are exposed in Greenwood County. While the foregoing factors do contribute to the greater productivity of the slate belt rocks, they have a negative aspect also. The greater abundance of void spaces in these rocks decreases their degree of consolidation and accounts for the fact that surface casing must be set to much greater depths in the slate belt rocks than in other rock types.

Table 3. Yields of wells from various metamorphic belts and plutonic rocks in Greenwood County, South Carolina.

Metamorphic belt or pluton	Median Yield gpm	Range gpm	Number of Wells
Carolina Slate Belt	28	2 - 100	22
Charlotte Belt	17	0 - 100	91
Kings Mountain Belt	15	0 - 150	51
Mulberry Creek Granite	22	0 - 50	9
Coronaca Granite-Syenite	15	0 - 35	20
Greenwood Pluton	17	6 - 100	12
Verdery Gabbro	6	—	1
All rock types	17	0 - 150	206

Relation of well yields to topography and linear features. Previous studies have shown that most natural linear topographic features which occur in the Piedmont are caused by vertical or steeply dipping joints and fault zones (Snipes, 1981; Snipes *et al.*, 1983; Stafford *et al.*, 1983). In addition, fold axes and steeply dipping or vertical dolerite dikes frequently have a linear aspect (Snipes and Furr, 1979; Snipes *et al.*, 1983). These features cause vegetation or soil tonal alignments which often are expressed on aerial photographs, satellite imagery, or topographic maps. Such linear features are called lineaments, if their length is equal to or greater than 1.5 km, while they are termed fracture traces, if their length is less than 1.5 km (Lattman, 1958). The lineaments and fracture traces of Greenwood County are shown in figure 2 (in pocket).

In Abbeville County, situated just west of Greenwood County, four major fault zones have been reported including: (1) the Lowndesville Belt (Price, 1969; Griffin, 1978), the Cold Spring Shear (Griffin, 1979), and the Calhoun Falls and Watts Cataclastic Zones (Snipes *et al.*, 1983). In the present investigation we attempted to trace these fault zones across Greenwood County. This was difficult because good, continuous exposures of fault rocks are not common in this county. Thus, our interpretations are based upon a few good outcrops, float fragments consisting of mylonite, phyllonite and silicified breccia, and analyses of aerial photographs, satellite imagery and topographic maps.

Fragments of mylonite and phyllonite occur along the N65°E trend of the Lowndesville Belt in northern Greenwood County, but good, continuous outcrops were not observed. Perhaps the Lowndesville Cataclastic Zone merges with the Cold Springs Shear, near the Greenwood - Laurens

County line, but this interpretation is only tentative because of poor outcrop control. Moreover, the vegetative or soil tonal alignments, which occur on aerial photographs along this trend, are discontinuous. Thus, the extension of the Lowndesville Belt across Greenwood County is highly speculative.

In Abbeville County, the Cold Springs and the Calhoun Falls Zones merge near the center of the county and continue for a distance of 7 miles on a N50°E trend to the vicinity of the Greenwood County line (Snipes et al., 1983). Approximately ½ mile west of the county line this zone appears to split into two branches. On the basis of a few good outcrops and the common occurrence of float fragments, one of the branches extends N45°E across Greenwood County and into Laurens County. Another branch, believed to be a splay off the Cold Springs zone, strikes N70°E, and good outcrops of quartz mylonite and biotite phyllonite can be traced for a distance of about ½ mile east of the Abbeville - Greenwood County line. In addition, on the basis of mylonite float fragments this splay extends another 2½ miles eastward.

The N45°E trending Watts Cataclastic Zone extends across Abbeville County but near the Greenwood County line good outcrops were not observed. However, numerous quartz mylonite float fragments occur along the projected strike of the Watts zone, and on this basis we tentatively have extended the Watts Zone northeastward into Greenwood County for a distance of three miles.

A well exposed zone of steeply-to-vertically dipping mylonitic rocks occurs in the Mulberry Creek Granite of northeastern Greenwood County (fig. 2). This zone is 50 to 100 yards in width, strikes N60°E, and it has been traced for a distance of 3 miles in Greenwood County to the Laurens County line. Because of time constraints we have not attempted to map these mylonitic rocks in Laurens County.

A southern splay off the Watts Cataclastic Zone shown on the Abbeville County map of Snipes et al. (1983) continues into Greenwood County along a strike of N70°E for a distance of 4 miles. This zone was mapped mainly on the basis of cataclastic float fragments. It occurs very near the contact between the Kings Mountain and Charlotte Belts (fig. 2). In addition to the foregoing major cataclastic zones, numerous other zones were observed, but they were too small to be plotted on a county map.

Most of the other lineaments and fracture traces shown in figure 2 were caused by steeply dipping systematic joints. More than 150 such features were plotted.

In table 4 the yields of wells with respect to topography and linear features are listed. The wells situated in the valleys had the best median yield (35 gpm), which was about twice as much as the ridges and slopes (17 gpm), and about three times that of the hills (12 gpm). The valleys also had the largest percentage of wells with yields of 50 gpm or more (26%), which was about 5 times more than the ridges (5%) and slopes (6%), and 10 times more than the hills (2.5%). The median yield of the fracture traces and lineaments was 25 gpm, which was about twice as much as the nonlinear features (12 gpm). In tables 5 and 6 the median yields with respect to topographic and linear features are listed for Greenwood, Abbeville, Oconee, Pickens, and Anderson Counties. A study of this data leads to the following conclusions:

Table 4. Relation of well yields to topography and linear features.

Yields gpm		Percentages of topographic features				Percentages of linear or nonlinear features	
≥	<	Valley	Slope	Hill	Ridge	Fracture Traces and Lineaments	Nonlinear Features
0	2	0.0	7.9	0.0	9.5	0.0	6.8
2	5	3.2	6.1	12.5	9.5	0.0	9.3
5	10	3.2	12.3	25.0	23.8	4.5	17.4
10	15	12.9	22.8	20.0	4.8	13.3	20.5
15	20	19.4	25.4	12.5	14.3	17.8	21.7
20	30	9.7	11.4	20.0	4.8	15.6	11.2
30	40	19.4	6.1	2.5	23.8	17.8	6.8
40	50	6.5	1.8	5.0	4.8	6.7	2.5
50	60	3.2	1.8	2.5	4.8	2.2	2.5
60	100	6.5	1.8	0.0	0.0	6.7	0.6
100	-	16.1	2.6	0.0	0.0	15.5	0.6
Median Yield		35	17	12	17	25	12
Number of Wells		31	114	40	21	45	161

Table 5. Median yield of drilled wells with respect to topographic features in some Piedmont counties of South Carolina.

Topographic Feature	Median yields, gpm		
	Greenwood County (Present investigation)	Abbeville County (Snipes *et al.*, 1983)	Oconee, Anderson, and Pickens Counties (Snipes, 1981)
Valley	35	25	15
Ridge	17	35	12
Slope	17	7	5
Hill	12	1	4
Number of Wells	206	111	237

Table 6. Median yield of drilled wells with respect to fracture traces and lineaments in some Piedmont Counties of South Carolina.

Linear or Nonlinear Features	Median yields, gpm		
	Greenwood County (Present investigation)	Abbeville County (Snipes *et al.*, 1983)	Oconee, Anderson, and Pickens Counties (Snipes, 1981)
Lineaments and fracture traces	25	35	20
Nonlinear features	12	5	4
Number of Wells	206	111	237

1. The highest yields were from the valleys in Greenwood County; while in Abbeville County the largest yields were from the ridges. In Anderson, Oconee and Pickens Counties the productivities from the valleys were somewhat better than the ridges. Snipes et al. (1983) felt that the explanation for the fact that the ridges were more productive than the valleys in Abbeville County was structural control. This opinion was based on studies of structural maps of Griffin (1978, 1979) on a scale of 1:24,000. It was found that many of the high producing wells situated along ridges were located along the axes of synforms. Unfortunately, detailed structural maps of Greenwood County were not available. However, a study of the reconnaissance map of Overstreet and Bell (1965b) shows that plutonic rocks and the Carolina Slate Belt together occupy a significantly greater percentage of the area in Greenwood County than in Abbeville. Thus, we feel that lithologic control of well productivity is perhaps more important in Greenwood County than it is in Abbeville.
2. In Greenwood County, the productivities of the slopes and ridges were the same, but in the other counties the yields of the ridges were about 2 to 5 times greater than the slopes.
3. The yields of the hills were the poorest in all of the counties, and the productivities of the valleys were 3 to 25 times greater than the hills.
4. The yields of the fracture traces and lineaments were 2 to 7 times greater than the nonlinear features.

WATER QUALITY

One hundred and eleven ground water samples from Greenwood County were analyzed for hardness, pH, alkalinity, Cl, Mn, Zn, and Cu (table A2). Ninety of the samples were from drilled wells, 11 were from bored wells, and 10 were from hand dug ones. In addition, 59 samples were analyzed for total dissolved solids, 70 Ca determinations were made, and 18 Mg analyses were reported (table A2). The analyses were performed by SC DHEC.

The ranges and the medians of each of the chemical parameters are listed in table 7. In addition, the limits recommended by SC DHEC are tabulated.

With regard to total dissolved solids and hardness, most of the samples were of good to excellent quality. Only 1.7 and 4.5 percent of the samples respectively exceeded the maximum concentrations recommended for total dissolved solids and hardness. The total dissolved solid content varied from 8.8 to 1,500 mg/1, while the median was 110 mg/1. The hardness values varied from 10 to 895 mg/1, and the median was 40 mg/1.

The principal problem of ground water quality in Greenwood County was the low pH. The median pH value of 6.4 was below the lower limit of 6.5 recommended by SC DHEC. Furthermore, 28 percent of the samples had pH values which were between 6.4 and 6.0, and 25 percent had values which were below 6. Thus, much of the ground water samples of this county are moderately to very corrosive.

The iron content varied from <0.05 mg/1 to 6.0 mg/1, and the median was <0.1. Manganese varied from <0.05 to 0.5 mg/1, while the median was

Table 7. Data on chemical analyses of water well samples, Greenwood County, South Carolina.

Parameter		Range	Median	Limits Recommended by SC DHEC
Total dissolved solids	mg/l	8.8 - 1500	110	500
Hardness	mg/l	10 - 895	40	50 - 150
pH		4.8 - 7.8	6.4	6.5 - 8.5
Alkalinity	mg/l	4 - 151	42	> 30
Chloride	mg/l	0.5 - 40	4.0	250
Ca	mg/l	0.4 - 200	8.0	—
Mg	mg/l	0.35 - 7.0	2.25	—
Fe	mg/l	<0.05 - 6.0	<0.1	0.3
Mn	mg/l	<0.05 - 0.5	<0.05	0.05
Zn	mg/l	<0.05 - 10.0	0.1	5.0
Cu	mg/l	<0.05 - 4.5	<0.1	1.0

<0.05. Fourteen percent and 10% of the samples respectively exceeded the limits recommended for Fe and Mn. Excessive concentrations of both of these elements cause scaling in pipes, and discoloration of clothing and bathroom fixtures. Zinc and copper determinations were favorable. Only two percent of the samples exceeded the maximum concentrations recommended for both Zn and Cu.

The median values of chemical analyses of water well samples of Greenwood, Abbeville, Oconee, Anderson, Pickens, and Spartanburg Counties are listed in table 8. The median values of total dissolved solids and hardness were somewhat higher in Greenwood County than they were in the other counties, while the concentrations of Cl, Ca, Mg, Fe, and Mn were not significantly different. The pH value of 6.4 for Greenwood County was the median for all of the counties listed.

In tables 9 through 16 the ranges and median values of the chemical parameters are listed according to metamorphic belts, mylonitic rocks, and plutonic rocks. The highest maximum concentrations of total dissolved solids were from the Kings Mountain Belt, the mylonitic rocks, and the Greenwood Pluton, which were respectively 1500, 1200, and 1000 mg/l. Despite these high concentrations, all of the median values of total dissolved solids as well as hardness were appreciably below the limits recommended by SC DHEC. In fact, with the exception of the pH, all of the median values were quite satisfactory. The median pH values of the samples from the Charlotte Belt, the Carolina Slate Belt, the Mulberry Creek Granite, and the Coronaca Granite-Syenite were all below 6.5, the lower limit recommended by SC DHEC, while the median values of the water from the mylonitic rocks (6.5) and the Kings Mountain Belt (6.6)

Table 8. Median values of chemical analyses of water well samples of Greenwood, Abbeville, Oconee, Anderson, Pickens, and Spartanburg Counties, South Carolina.

Parameter		Median Values				
		Greenwood County this report	Abbeville County (Snipes *et al.*, 1983)	Oconee, Anderson, Pickens Counties (Snipes, 1981)	Pickens County (Johnson *et al.*, 1968)	Spartanburg County (Bloxham *et al.*, 1970)
Total dissolved solids	mg/l	110	72	19	75	85
Hardness	mg/l	40	23	14	16	34
pH		6.4	6.6	6.2	6.2	6.5
Chloride	mg/l	4.0	4.0	2.0	5.0	3.0
Ca	mg/l	8.0	8.0	2.8	6.3	8.5
Mg	mg/l	2.25	3.0	0.9	1.3	2.2
Fe	mg/l	<0.1	<0.1	0.10	0.04	0.04
Mn	mg/l	<0.05	<0.05	<0.01	0.02	0.02

Table 9. Data on four chemical analyses of water well samples from the Carolina Slate Belt, Greenwood County, South Carolina.

Parameter		Range	Median	Limits Recommended by SC DHEC
Total dissolved solids	mg/l	76 - 230	133	500
Hardness	mg/l	50 - 77	75	50 - 150
pH		6.0 - 7.5	6.2	6.5 - 8.5
Alkalinity	mg/l	20 - 95	43.5	>30
Chloride	mg/l	1.0 - 40	15.5	250
Ca	mg/l	4.0 - 10.0	7.0	-
Mg	mg/l	-	-	-
Fe	mg/l	0.06 - 0.43	<0.1	0.3
Mn	mg/l	<0.05	<0.05	0.05
Zn	mg/l	<0.1 - 0.39	0.26	5.0
Cu	mg/l	<0.05 - <0.1	0.07	1.0

Table 10. Data on sixty-three chemical analyses of water well samples from the Charlotte Belt, Greenwood County, South Carolina.

Parameter	Range	Median	Limits Recommended by SC DHEC
Total dissolved solids mg/l	8.8 - 310	100	500
Hardness mg/l	13 - 460	38	50 - 150
pH	5.1 - 7.8	6.4	6.5 - 8.5
Alkalinity mg/l	20 - 151	41	>30
Chloride mg/l	1.5 - 19.5	4.0	250
Ca mg/l	0.4 - 80	8.0	-
Mg mg/l	1.0 - 4.2	2.6	-
Fe mg/l	<0.05 - 6.0	<0.1	0.3
Mn mg/l	<0.05 - 0.13	<0.05	0.05
Zn mg/l	<0.05 - 3.0	0.1	5.0
Cu mg/l	<0.05 - 4.5	<0.1	1.0

Table 11. Data on twenty-nine chemical analyses of water well samples from the Kings Mountain Belt, Greenwood County, South Carolina.

Parameter		Range	Median	Limits Recommended by SC DHEC
Total dissolved solids	mg/l	56 - 1200	110	500
Hardness	mg/l	13 - 895	46	50 - 150
pH		4.8 - 7.5	6.6	6.5 - 8.5
Alkalinity	mg/l	4.0 - 124	52	>30
Chloride	mg/l	0.5 - 29	4.0	250
Ca	mg/l	6 - 200	10.0	-
Mg	mg/l	0.39 - 5.0.	2.4	-
Fe	mg/l	<0.05 - 2.5	<0.1	0.3
Mn	mg/l	<0.05 - 0.15	<0.05	0.05
Zn	mg/l	<0.05 - 8.0	0.12	5.0
Cu	mg/l	<0.05 - 0.14	<0.1	1.0

Table 12. Data on five chemical analyses of water well samples from mylonitic rocks, Greenwood County, South Carolina.

Parameter		Range	Median	Limits Recommended by SC DHEC
Total dissolved solids	mg/l	72 - 1000	96	500
Hardness	mg/l	14 - 895	22	50 - 150
pH		4.8 - 7.5	6.5	6.5 - 8.5
Alkalinity	mg/l	4.0 - 56	29	>30
Chloride	mg/l	2.0 - 13.5	3.5	250
Ca	mg/l	10.0	10.0	-
Mg	mg/l	2.9	2.9	-
Fe	mg/l	<0.05 - 0.5	<0.1	0.3
Mn	mg/l	<0.05 - 0.08	<0.05	0.05
Zn	mg/l	<0.05 - 0.8	0.1	5.0
Cu	mg/l	<0.05 - <0.1	<0.05	1.0

Table 13. Data on five chemical analyses of water well samples from the Mulberry Creek Granite, Greenwood County, South Carolina.

Parameter		Range	Median	Limits Recommended by SC DHEC
Total dissolved solids	mg/l	90 - 120	100	500
Hardness	mg/l	10 - 51	22	50 - 150
pH		5.0 - 6.5	6.2	6.5 - 8.5
Alkalinity	mg/l	10 - 78	27	>30
Chloride	mg/l	3.5 - 19.0	7.2	250
Ca	mg/l	7.5 - 9.0	8.2	-
Mg	mg/l	2.0 - 7.0	4.5	-
Fe	mg/l	<0.1 - 1.8	<0.1	0.3
Mn	mg/l	<0.05 - 0.5	<0.05	0.05
Zn	mg/l	<0.05 - 0.8	0.11	5.0
Cu	mg/l	<0.05 - 0.8	<0.05	1.0

Table 14. Data on nine chemical analyses of water well samples from the Coronaca Granite-Syenite, Greenwood County, South Carolina.

Parameter		Range	Median	Limits Recommended by SC DHEC
Total dissolved solids	mg/l	100 - 110	105	500
Hardness	mg/l	14 - 40	26	50 - 150
pH		5.1 - 6.7	5.8	6.5 - 8.5
Alkalinity	mg/l	9 - 54	24	>30
Chloride	mg/l	2.5 - 19.0	4.5	250
Ca	mg/l	3.0 - 13.0	5.0	-
Mg	mg/l	-	-	-
Fe	mg/l	<0.1 - 0.9	<0.1	0.3
Mn	mg/l	<0.05	<0.05	0.05
Zn	mg/l	<0.05 - 0.5	0.08	5.0
Cu	mg/l	<0.05 - 1.0	<0.1	1.0

Table 15. Data on six chemical analyses of water well samples from the Greenwood Pluton, Greenwood County, South Carolina.

Parameter		Range	Median	Limits Recommended by SC DHEC
Total dissolved solids	mg/l	35 - 1500	128	500
Hardness	mg/l	14 - 60	33.5	50 - 150
pH		5.7 - 7.6	6.7	6.5 - 8.5
Alkalinity	mg/l	13 - 72	37.5	>30
Chloride	mg/l	1.5 - 5.0	4.0	250
Ca	mg/l	3.8 - 16.0	12.5	-
Mg	mg/l	0.35 - 5.4	2.65	-
Fe	mg/l	<0.05 - 3.0	0.07	0.3
Mn	mg/l	<0.05	<0.05	0.05
Zn	mg/l	<0.05 - 1.5	0.2	5.0
Cu	mg/l	<0.05 - 1.0	0.12	1.0

Table 16. Data on two chemical analyaes of water well samples from the Verdery Gabbro, Greenwood County, South Carolina.

Parameter		Range	Median	Limits Recommended by SC DHEC
Total dissolved solids	mg/l	130 - 140	135	500
Hardness	mg/l	56 - 78	67	50 - 150
pH		7.2 - 7.3	7.2	6.5 - 8.5
Alkalinity	mg/l	57 - 79	68	>30
Chloride	mg/l	2 - 5	3.5	250
Ca	mg/l	-	-	-
Mg	mg/l	-	-	-
Fe	mg/l	0.1	0.1	0.3
Mn	mg/l	<0.05	<0.05	0.05
Zn	mg/l	0.1 - 0.4	0.25	5.0
Cu	mg/l	<0.1	<0.1	1.0

were on the border line. The lowest median pH, 5.8, occurred in the Coronaca Granite-Syenite. The highest median values were from the Greenwood Pluton (6.7) and the Verdery Gabbro (7.2), but only 2 ground water samples were analyzed from the latter igneous intrusive.

HYDROLOGICAL PROBLEMS ON THE PAX MOUNTAIN FAULT ZONE, A CASE HISTORY

Despite the fact that a great number of successful wells have been drilled utilizing fracture trace mapping, this method sometimes fails because of several geological problems: (1) some of the fault zones are occupied by unconsolidated rocks, and such wells usually cave in just when they encounter large volumes of water, (2) some of the fault rocks contain clay gouge which makes the water too muddy to drink, or in some cases clogs up the void spaces between the coarse particles, (3) some of the joints and faults have been filled with secondary quartz causing dry holes, and (4) at some of the well sites where the rocks contain open joints the ground water has migrated downdip away from the well site.

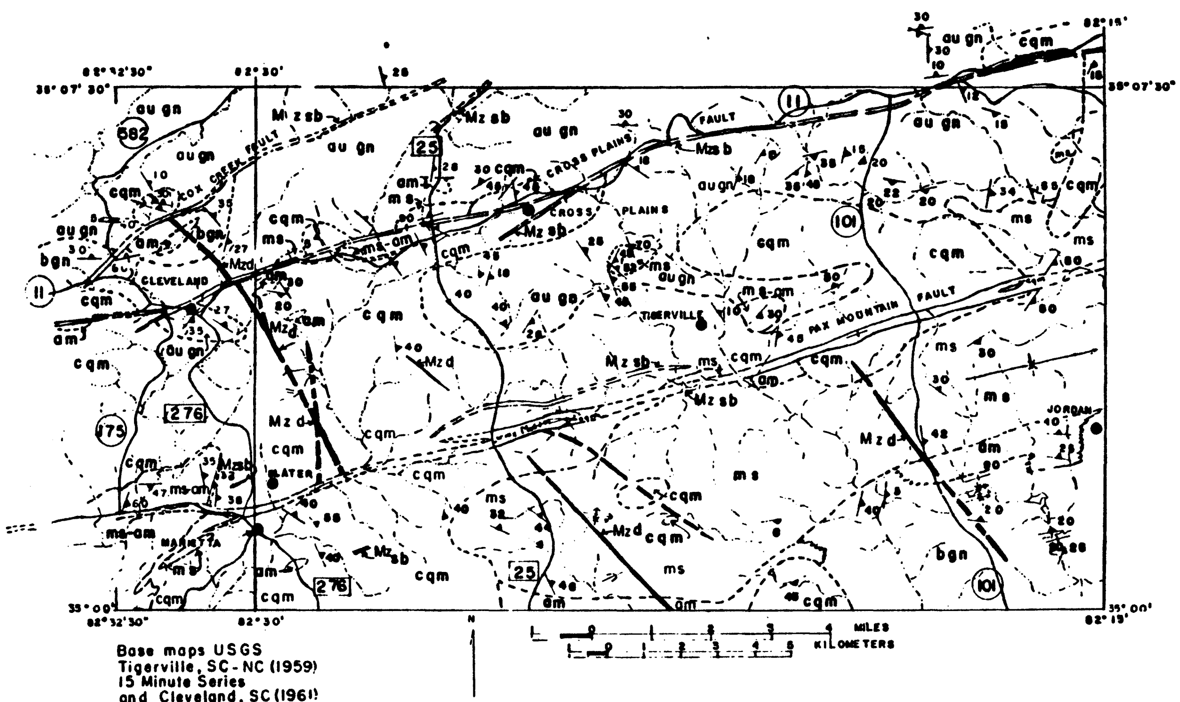
Our studies of the hydrological conditions at Pax Mountain, a scenic subdivision whose growth has been seriously curtailed by the shortage of ground water, demonstrate some of the problems encountered in drilling for water in linear features in upstate South Carolina. Situated in the Inner Piedmont about 14 miles north of Greenville, Pax Mountain is a steep, narrow ridge which has a length of 1.6 miles and a height of 330 feet. The Pax Mountain Fault Zone is named for this conspicuous ridge. This fault strikes N70°E, dips vertically or nearly so, extends across Greenville and Spartanburg Counties, and terminates in Rutherford

County, North Carolina, a distance of about 50 miles (Conley and Drummond, 1965). It forms a very prominent lineament on satellite imagery. A geologic map of a portion of the Pax Mountain Fault is shown in figure 6.

Until recent drilling operations in the early part of 1984, we felt that this fault zone was occupied mainly by consolidated, silicified fault breccia consisting of more than 95 percent quartz. This opinion was based on observations of surface rock exposures. Studies of well cuttings and of subsurface data obtained from well drillers, who drilled 6 wells along the axis of Pax Mountain and one near its base, show that the composition of the fault rocks is more complex and much more interesting than was previously known.

One of the wells situated on the axis of this ridge was drilled to a depth of 390 feet. This is the deepest well drilled along a known fault in the Piedmont. The depth of the other wells drilled along this axis varied from 260 to 350 feet, while the one drilled near the base of the ridge had a depth of 190 feet. Fortunately, while drilling operations were in progress, a basement was excavated just 60 feet north of one of the deep wells. Thus, we were able to observe the texture and the composition of the fault rocks in a vertical section and compare this excellent exposure with our subsurface data. X-ray and microscopic studies showed that the mineral composition of the cuttings from the wells to a depth of 330 feet and the composition of the fault rocks exposed in the basement were virtually identical.

The rocks exposed in the basement excavation are shown in figure 7. They consist of fault breccia enclosed in a brown-to-reddish matrix of clay gouge. The coarse particles are dominantly quartz with subordinate



GEOLOGY OF THE SOUTHERN HALF OF THE TIGERVILLE AND THE EASTERN PORTION OF THE CLEVELAND QUADRANGLES

By

D.S. Snipes, M.W. Davis and P. R. Manoogian

Figure 6.

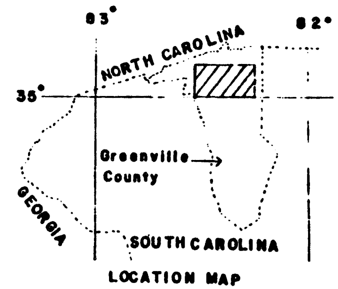
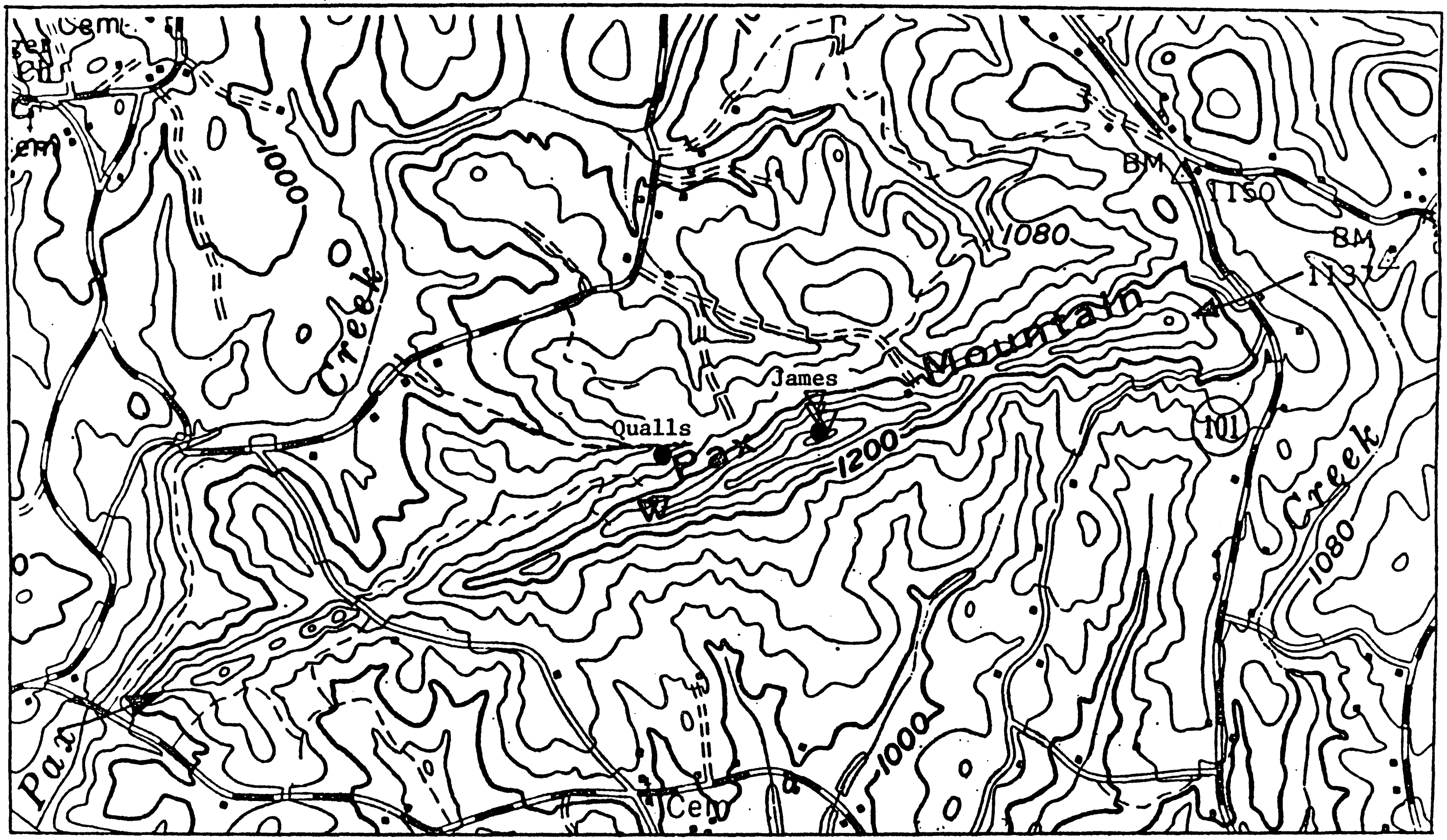


Figure 7. Fault breccia and clay gouge from the Pax Mountain Fault Zone. The breccia consists of coarse, angular particles, while the gouge consists dominantly of fine, dark colored clay.

K-feldspar and plagioclase, while the clay size particles consist mostly of kaolinite with a minor amount of iron oxide. The rocks vary greatly in their degrees of consolidation and permeability, and these variations were the cause of some serious ground water exploration problems.

In figure 8, the locations of 5 abandoned wells and 2 productive ones are shown. Because of the poor consolidation of the fault breccia, three of the wells situated on the James property caved in at a depth of about 260 feet just when they had encountered large volumes of water. A fourth well at this site produced more than 25 gpm. At the Qualls property, situated 0.4 mi southwest of the James property, two wells drilled to depths of 350 and 390 feet respectively, were dry holes because of the poor permeability of the fault breccia. A third well, situated about 200 yards north of the dry holes, penetrated 130 feet of fault breccia and encountered a slice of fractured granite at depths of 130 - 150 feet. Within this interval the well tested 5 gpm of clear water. In an effort to obtain a larger water supply, drilling was continued to a depth of 190 feet. Within this last interval of 40 feet the well tested an additional 10 gpm, but this water was too muddy to drink. However, a pump was set at a shallower depth within the granitic slice and at this writing the granitic interval produces potable water.

The foregoing case history together with our studies in five other counties points to the need for the application of geophysical methods to ground water exploration. Seismic methods should be utilized to determine the degree of consolidation of the fractured rocks, while



N

Base Map
USGS
Tigerville, SC-NC
1959
15 Minute Series

1 5 0 1 KM

Contour Interval 40 feet

EXPLANATION

● Productive Well
▽ Dry Well
→ ← Part of the Pax Mountain Fault Zone
– – – – Fracture Trace

Figure 8. Location of some productive and abandoned wells along a portion of the Pax Mountain Fault Zone, Greenville County, SC.

resistivity methods can be used to detect the presence or absence of ground water. The application of these techniques should minimize the risk of drilling expensive non-productive wells and help find much greater supplies of ground water in the Piedmont, Appalachian, and other provinces.

MAGNETOMETER STUDIES OF BASIC IGNEOUS ROCKS

Introduction. A large number of dark colored, basic igneous plutons occur within the Piedmont of South Carolina. These rocks are generally much higher in calcium, magnesium, and iron than the lighter colored, quartz-rich igneous rocks and most of the metamorphic ones as well. Accordingly, the ground water obtained from wells drilled in the basic igneous rocks tends to have a higher content of total dissolved solids, a greater hardness, and a higher pH than the water obtained from the lighter colored igneous and metamorphic ones. In some instances the water quality is impaired by the high content of these elements, particularly by iron, to the point that it is not suitable for domestic, public, or industrial use, or requires treatment.

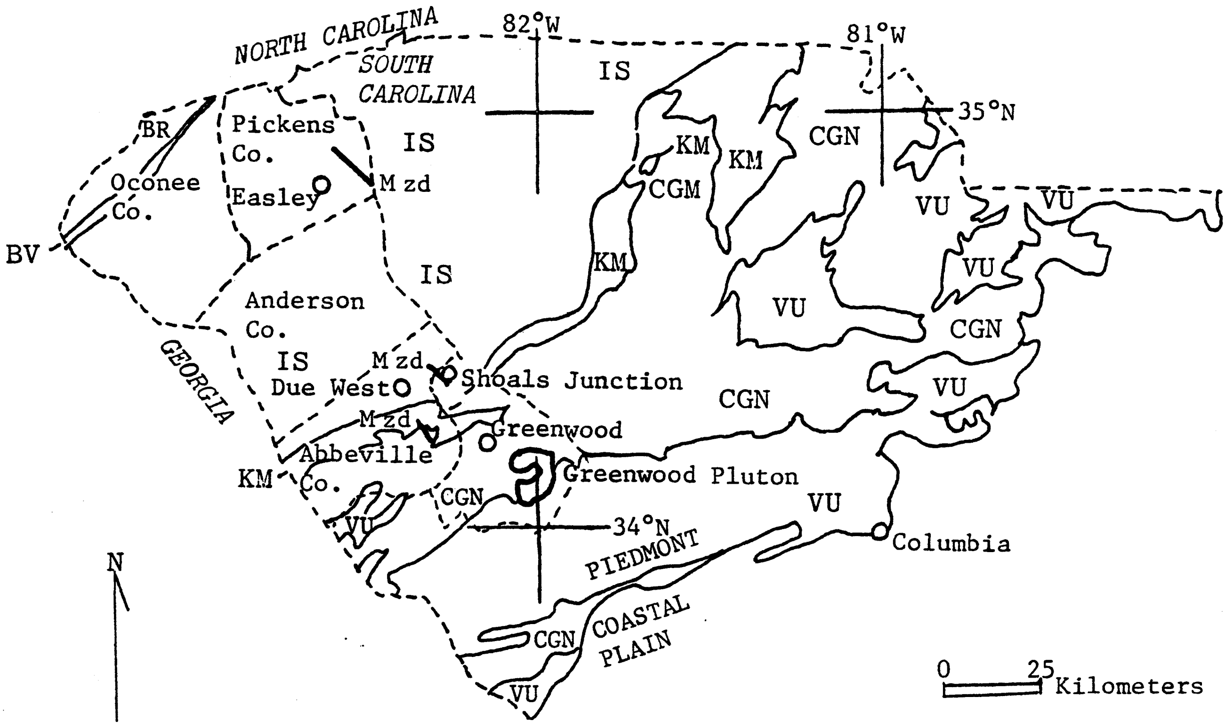
Because most of the dark colored igneous rocks, mainly gabbros and dolerites, generally contain about 1 - 3 percent magnetite (Fe_3O_4), they can be mapped by means of a magnetometer. This fact is important because such rocks often are covered by forests or pasture grass and good outcrops occur infrequently.

The instrument utilized in this investigation was a portable Fluxgate Magnetometer, MF-2/100, Scintrex, Inc.. In order to check on the reproducibility of the measurements, readings were made at a standard station, a gneiss outcrop, situated on the Clemson University Campus (Lat.34°40'08" N, Long. 82°50'30"). This gneiss consists dominantly of quartz and plagioclase with minor amounts of K-feldspar and hornblende. Measurements were made at the beginning of each field day and on some occasions twice per day. Twelve measurements were made during a 10 month interval (9/24/83 - 7/26/84). The magnetic intensity varied from 46 x 10^3 gammas to 72 x 10^3 gammas, while the median was 60 x 10^3 gammas. We found that when measurements were made at the beginning and the end of each field day, the agreement was close (within 4 x 10^3 gammas). Thus, all of the measurements for a given profile were made on the same day.

Magnetic profiles were made on four basic intrusives including the Shoals Junction and Due West Dolerites of this report, the Easley Dolerite (Snipes and Furr, 1979), and the Greenwood Gabbro (Chalcraft, 1981).

<u>Shoals Junction, Due West, and Easley Dolerites</u>. These three dikes were selected for the magnetometer study from the numerous doleritic intrusives which occur in the Piedmont of this state for the following reasons: (1) the Shoals Junction and Due West Dolerites had not been reported previously in the literature, (2) these two dolerites were poorly exposed and magnetometer studies were needed in order to map the rocks, and (3) the third dike, the Easley Dolerite (Snipes and Furr, 1979) was known to have some better exposures than the other two and a study of it would be useful in order to interpret the data from the more poorly exposed ones.

The locations of these doleritic intrusives are shown in figure 9. The Shoals Junction and Easley Dolerites are situated within the Inner Piedmont Belt of Overstreet and Bell, 1965a, while the Due West Dolerite



EXPLANATION

Mesozoic Dolerite Dikes

M zd

Paleozoic Belts

VU	Carolina Slate Belt	BV	Brevard Belt
CGN	Charlotte Belt	BR	Blue Ridge Belt
KM	Kings Mountain Belt	IS	Inner Piedmont Belt

Figure 9. Index map showing the Shoals Junction, Due West, and Easley dolerites, and the Greenwood Pluton. The geologic belts of the Piedmont are modified from Overstreet and Bell (1965a) and Griffin (1978).

is located mainly within the Charlotte Belt, but extends northward into the Kings Mountain Belt.

Because of their vertical or nearly vertical dip, the doleritic dikes are expressed as linear features on topographic maps and aerial photographs, and because they exceed 1.5 km in length, they are termed lineaments. Studies by Steele and Ragland (1976), Chalcraft (1976), de Boer and Snider (1976), and Snipes and Furr (1979) suggest that the dolerites were emplaced in steeply dipping extensional fractures during Mesozoic time, perhaps during the Late Triassic or Early Jurassic.

The Shoals Junction Dolerite is named herein for the village of Shoals Junction, which is situated 14 miles NNW of the city of Greenwood (fig. 9). The type section is located 82°18'07" W longitude and 34°20'15" N latitude, 0.2 miles ENE of the intersection of U.S. Highway 178 and SC Highway 420. Here the outcrop is about 10 yards wide with an additional 20 yard wide exposure of float. Elsewhere, the dolerite outcrops are few in number and occur in streams or along ridges. For the most part the outcrops are less than 1 yard in width and 5 yards in length, however cobbles and boulders of dolerite float are common and occasionally such exposures attain a width of more than 380 yards.

The length of the Shoals Junction Dolerite is approximately 5 miles. Its northern termination is in Abbeville County, about 1.6 miles north of the county line, while its southern end is in Greenwood County, about 3.4 miles south of the county line. Its strike varies from N32°W to N50°W, but the dominant trend is N40°W. Its dip is vertical or nearly so.

The Due West Dolerite is named herein for a locality (Lat.34°11'27" N and Long. 82°19'07" W) adjacent to Abbeville County Road 51, situated 10 miles SSE of Due West, South Carolina (fig. 9). Its length is approximately 2.5 miles and its width varies from less than 1 yard to more than 220 yards. Its strike is N34°W and its dip is vertical or nearly so.

Microscopic studies were made on two representative samples of the Shoals Junction Dolerite and on three specimens from the Due West Dolerite. The rock is inequigranular with supophitic to ophitic textures. The grain sizes of two of the samples are listed in table 17. Specimen SJ-23 is representative of the fine grained dolerite, while sample SJ-22 is representative of the somewhat coarser rocks.

Modal analyses are listed in table 18. The essential minerals are plagioclase (46 - 56%), pyroxene (21 - 39%), and olivine (7 - 20%). The opaque minerals (1 - 2%) consist mainly of ilmenite - magnetite, while the alteration minerals (2 - 6%) are chiefly chlorite and serpentine. Cryptocrystalline material to partly glassy mesostasis (0.2 - 1.1%) occurs in the spaces between the principal minerals.

Along most of its length, the Shoals Junction Dolerite is interpreted to be a swarm of small dikes instead of a single intrusive. This is based upon observations at several localities and magnetometer surveys.

At one locality (Lat. 34°22'25" N and long. 82°19'35" W) near the northern edge of the Shoals Junction 7½ minute quadrangle, three small vertical dolerite dikes, each having a width of about 1 foot were observed. These dikes had intruded granitic material and they were spaced about 15 yards apart. Moreover, to the northeast, perpendicular to the strike of the doleritic rocks for a distance of about 200 yards, scattered cobbles and boulders of dolerite float occur in a light colored, sandy soil which we feel was derived from the weathering of granitic rocks.

Sample Number	Dimension	Grain Size mm								
		Plagioclase			Pyroxene			Olivine		
		Range		Median	Range		Median	Range		Median
SJ-22	Width	0.02	0.50	0.10	0.10	0.60	0.40	0.04	0.40	0.40
	Length	0.35	2.30	0.80	0.40	1.30	0.70	0.07	0.50	0.40
SJ-23	Width	0.01	0.30	0.05	0.04	0.40	0.07	0.05	0.15	0.07
	Length	0.07	0.70	0.15	0.05	0.60	0.06	0.06	0.15	0.07

Table 17. Grain sizes of the essential minerals of the Shoals Junction Dolerite.

Sample Number	Volume Percent						
	Plagioclase	Pyroxene	Olivine	Opaques	Mesostasis	Biotite	Alteration Minerals
SJ-22	53.8	21.8	20.0	1.9	0.7	-	1.8
SJ-23	55.6	21.4	17.3	1.5	0.2	-	3.9
DW-100	46.5	38.4	7.1	1.1	1.3	-	5.6
DW-105	46.8	38.9	7.1	1.1	1.1	-	5.0
DW-107	49.1	33.8	8.4	2.3	0.6	0.6	4.9

Table 18. Modal analyses of the Shoals Junction (SJ) and Due West (DW) Dolerites. The analyses were made by R. D. Warner.

The occurrence of predominantly light colored soil associated with dolerite float has been observed at several other localities as well, notably along a ridge (Lat. 34°21'37" N and Long 82°18'37" W) situated 1.3 miles south of the foregoing locality. Elsewhere in the Piedmont, if the rocks are mainly doleritic, the soils are predominantly dark red. Thus, the field observations suggest that the Shoals Junction Dolerite occurs as a swarm of multiple small dikes.

Magnetometer studies confirm the foregoing interpretation. In figure 10, magnetometer profiles of the Shoals Junction, Due West, and Easley Dolerites are shown.

The magnetic profile of the Shoals Junction Dolerite is much more irregular than those of the Due West and Easley Dolerites. Moreover, its maximum magnetic intensity, 36×10^3 gammas, is considerably less than those of the Due West and Easley dikes, which are 78×10^3 and 76×10^3 gammas respectively. These facts provide further evidence that the Shoals Junction Dolerite consists of a swarm of multiple small dikes.

We feel that these small dikes were emplaced in multiple fractures which occur either as faults or joints. Pebbles and cobbles of quartz mylonite float are associated commonly with the dolerite, but at this writing we have not been able to find a well-exposed contact between the dolerite and the mylonite in order to determine the relationship between the two.

Greenwood Pluton. This dark colored, massive igneous rock body was mapped by Overstreet and Bell (1965a) and Chalcraft *et al*. (1978). The latter investigators also made a Bouger gravity anomaly map of this

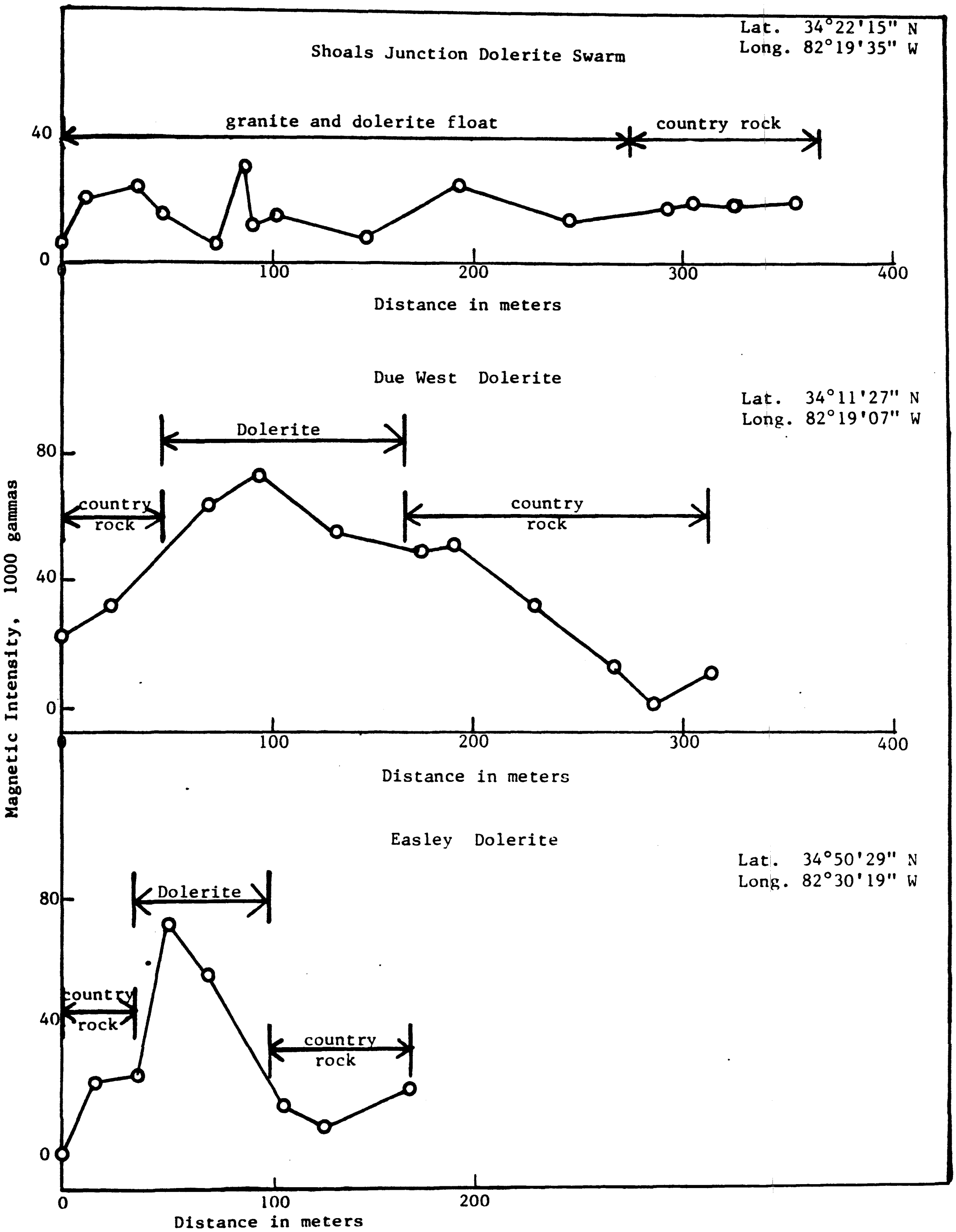


Figure 10. Magnetic profiles of the Shoals Junction, Due West, and Easley Dolerites. In order to eliminate negative values an arbitrary number has been added to the magnetic profile.

pluton and studied its petrography. This igneous rock body, shown in figure 9, intrudes rocks of the Charlotte and Carolina Slate Belts southeast of Greenwood, South Carolina (Chalcraft et al., 1978). The pluton is shaped like a horseshoe in map view, and it occupies an area of 60 square miles (Chalcraft et al., 1978).

The rocks of this pluton include diorite, gabbro and olivine gabbro (Chalcraft et al., 1978). Modal analyses are listed in table 19.

	Diorite	Gabbro	Olivine Gabbro
Plagioclase	51.0	50.9	62.4
Augite	5.9	20.3	13.3
Hypersthene	1.7	8.3	1.9
Olivine	-	11.0	17.5
Magnetite	3.9	2.7	3.0
Quartz	1.6	-	-
Biotite	2.9	4.0	0.5
Hornblende	25.7	2.7	1.2
Epidote	2.2	-	-
Chlorite	2.2	Trace	Trace
Apatite	Trace	-	-
Serpentine	-	Trace	-
	99.9	99.9	99.8

Table 19. Modal analyses of the rocks of the Greenwood Pluton. Values are in volume percent (Chalcraft et al., 1978).

Plagioclase is the dominant constituent in all of the rocks. Pyroxene (augite and hypersthene) and olivine are the principal mafic minerals of the gabbros, while hornblende is the main mafic constituent in the diorite. The diorite contains a minor amount of quartz, while this mineral was not reported in the gabbros. Magnetite (2.7 - 3.9%) occurs as an accessory mineral in all of the rocks.

Because much of the area is covered by vegetation or alluvium, the contacts between the pluton and the country rocks are obscure. Moreover, the gravimetric map of Chalcraft et al. (1978) was made from data obtained from gravity stations which had a 1 mile spacing. Thus, there is a need for more detailed and more accurate information in order to make predictions regarding the kinds of rocks expected when drilling water wells.

The utilization of the magnetometer to augment reconnaissance field mapping and gravimetric surveys in delineating the contacts between the country rocks and mafic rocks such as the Greenwood Pluton is an excellent technique because the magnetite content in it is 2.7 - 3.9%, whereas the content of this mineral is usually less than 1% in the surrounding rocks of the Carolina Slate and Charlotte Belts. A magnetic profile is shown in figure 11. Our survey indicates that the northeast boundary of the magnetic anomaly is about 1.2 mi southwest of the contact mapped by Chalcraft et al. (1978). This finding suggests that the area occupied by the Greenwood Pluton is significantly less than has been reported heretofore. In the future additional magnetic profiles need to be made in order to confirm or deny this opinion.

Water quality of the basic rocks. At this writing only one chemical analysis of a water sample from a well drilled in dolerite is available. Despite arduous efforts we were not able to locate a well which definitely

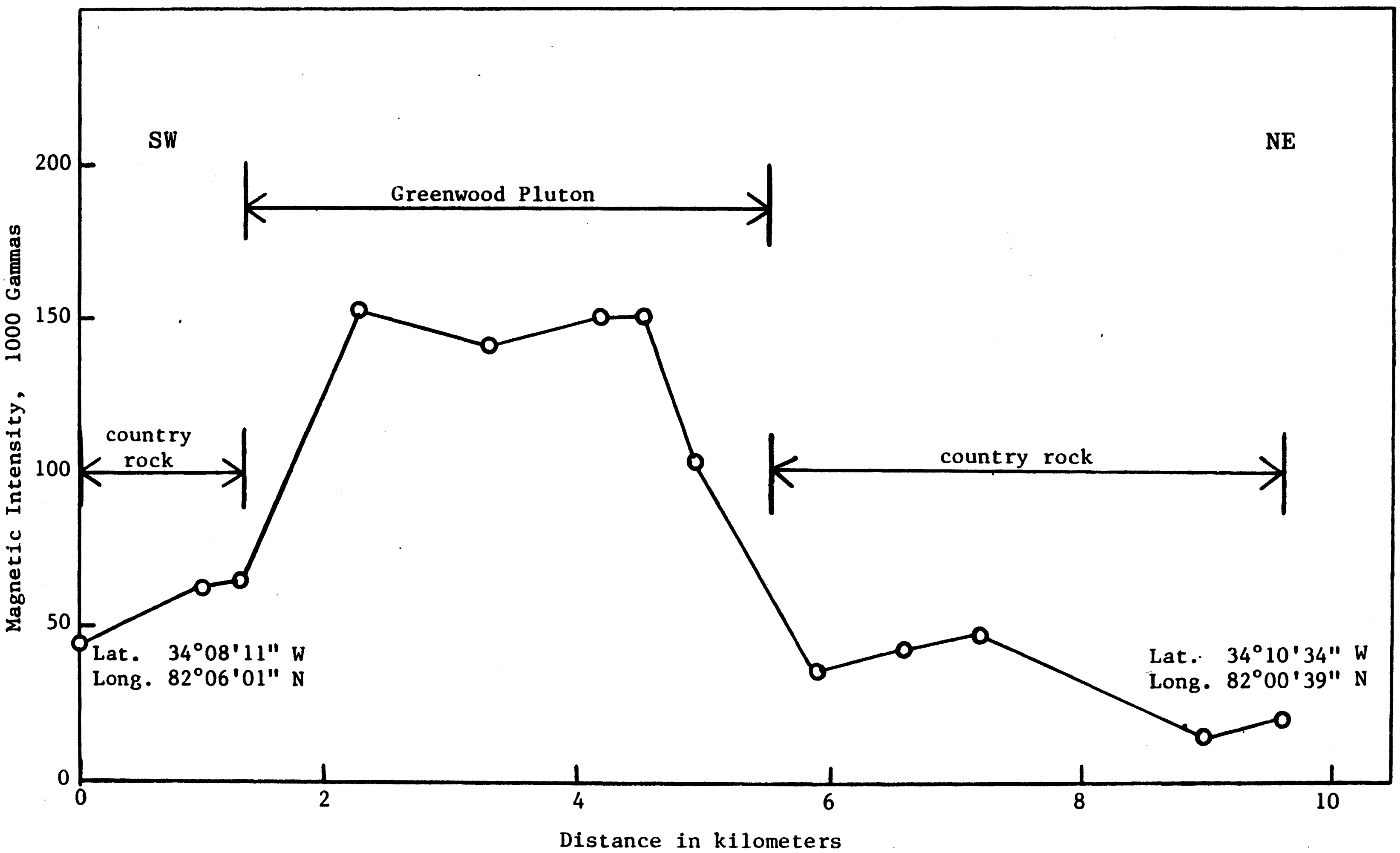


Figure 11. Magnetic profile of the Greenwood Pluton. In order to eliminate negative values an arbitrary number has been added to the magnetic intensity.

was situated in the Shoals Junction Dolerite, and because of time constraints, we have not attempted to collect water samples from the Easley Dolerite. Fortunately, however, we did find a well which had been drilled in the Due West Dolerite, and it was situated at the type section in Abbeville County. A chemical analysis of a water sample from this well together with the median chemical values of Abbeville County well water samples are listed in table 20.

Chemical parameter		Dolerite well	Median values of Abbeville County wells
Total dissolved solids	mg/l	74	72
Hardness	mg/l	26	23
pH		7.2	6.6
Alkalinity	mg/l	38	31
Chlorite	mg/l	2.0	4.0
Ca	mg/l	5.8	8.0
Mg	mg/l	2.7	2.7
Fe	mg/l	<0.05	<0.1
Mn	mg/l	<0.05	<0.05
Zn	mg/l	2.0	0.14
Cu	mg/l	0.73	0.05

Table 20. Chemical analysis of a ground water sample from a well drilled in the Due West Dolerite, and median chemical values of 71 Abbeville County wells. The dolerite well is situated in Abbeville County (Lat. 34°11'27" N and Long. 82°19'07" W). The median chemical values are from Snipes et al., 1983.

Surprisingly, most of the chemical values are similar with the exception of the pH and the amounts of Zn and Cu. The pH of 7.2 in the dolerite well is significantly higher than the median value of 6.6 for 71 Abbeville County wells. Nonetheless, its pH is satisfactory for domestic use. In addition, the Zn and Cu contents, which are respectively 2.0 mg/l and 0.73 mg/l, are within the limits prescribed for drinking water by SC DHEC.

Chemical analyses of six water well samples collected from the Greenwood Pluton are shown in table 21. Three of the wells were drilled ones, i.e., they penetrated basic igneous rocks, while three of the wells were bored or dug in soil, instead of bedrock. X-ray diffraction analyses of the cuttings from one of the drilled wells showed that the rock was diorite. The water from this well required treatment for hardness. It had a pH of 7.6, while the pH of the water from the other two drilled wells was 7.1. In the shallow wells which obtain their water from the soil or regolith the pH was much lower and it varied from 5.7 - 6.4. The low pH values are attributed to the removal of the more basic elements by water percolating downward through the soil.

SUMMARY AND CONCLUSIONS

This investigation dealt with field and laboratory studies on indicators of ground water quality and well yields from a variety of igneous, metamorphic, and fault rocks situated in the Piedmont of South Carolina. The principal study area was Greenwood County, which is occupied by the Carolina Slate, Charlotte, and Kings Mountain Belts of metamorphic rocks, and several large plutons. Magnetometer profiles were made on three basic dikes including the Easley Dolerite of Pickens

Table 21. Chemical analyses of water well samples collected from the Greenwood Pluton.

SCWRC Number	Type of Well*	TDS mg/l	Hardness mg/l	pH	Alkalinity mg/l	Cl mg/l	Ca mg/l	Mg mg/l	Fe mg/l	Mn mg/l	Zn mg/l	Cu mg/l	Remarks
42-O-f-1	B	35	<20	5.7	13	5.0	-	-	<0.1	<0.05	<0.1	0.2	Approximately on contact with Charlotte Belt Rocks.
43-N-j-1	HD	200	26	6.3	33	4.0	-	-	3.0	<0.05	0.30	1.0	
43-N-o-1	B	80	14	6.4	18	3.0	3.8	1.0	0.05	<0.05	<0.05	<0.05	Approximately on contact with Charlotte Belt rocks.
43-N-q-1	D	1500	41	7.6	42	5.0	16	0.35	<0.05	<0.05	0.05	<0.05	Water treated for hardness. Diorite well cuttings.
43-N-u-2	D	130	60	7.1	72	4.0	15	5.4	0.30	<0.05	1.5	0.35	
43-N-u-3	D	126	43	7.1	55	1.5	10	4.3	<0.05	<0.05	0.62	<0.05	

*Type of well: D - Drilled well
HD - Hand dug well
B - Bored well

County, the Due West Dolerite of Abbeville County, and the Shoals Junction Dolerite of Greenwood County. A magnetic profile was made also on a large, massive igneous intrusive, the Greenwood Pluton. In addition, a portion of the Mesozoic Pax Mountain Fault was investigated because it is one of the largest and most conspicuous lineaments in the Piedmont, and because studies of the data from seven recently drilled wells disclosed some very interesting hydrological problems. The foregoing field and laboratory studies have led to the following conclusions:

1. More than 150 lineaments and fracture traces were mapped in Greenwood County. These features were mapped from studies of aerial photographs, satellite imagery, and topographic maps. Field studies show that most of these features were caused by steeply dipping or vertical faults and joints. Other linear features were associated with fold axes or dolerite dikes.
2. While there are numerous exposures of fault rock float fragments in Greenwood County, good, continuous outcrops of fault rocks are not as common in this county as they are in Abbeville County, which is on its western border. Nevertheless, we have made some tentative interpretations regarding the extensions of the major faults of Abbeville County into Greenwood. Based on the occurrences of a few discontinuous outcrops and scattered fault rock fragments the Lowndesville Belt can be traced eastward from the county line for a mile or so into Greenwood County. Perhaps

it extends N65°E across the county into the adjacent Laurens County, but this interpretation is speculative because of poor outcrop control. The Cold Springs Shear and the Watts Zones appear to merge a few miles east of the county line, and scattered fragments of mylonite float trend N60°E toward an excellent outcrop of mylonite which occurs within the Mulberry Creek Granite. This mylonitic zone, which has a length of 3 miles, has been traced to the Laurens County - Greenwood County line.

3. The yields of 206 wells drilled in Greenwood County were obtained. The yields varied from 0 to 150 gpm, while the median was 17 gpm. The median yield of the wells situated in fracture traces and lineaments was 25 gpm, which was about twice the median yield of 12 gpm of the randomly located wells.

4. The median productivity of the wells situated in the Carolina Slate Belt was 28 gpm, while the median yields of the Charlotte and Kings Mountain Belts were 17 gpm and 15 gpm respectively. In addition, the median productivity of the Carolina Slate was higher than the median yields of the Mulberry Creek Granite, the Coronaca Granite-Syenite and the Greenwood Pluton, which were respectively 22 gpm, 15 gpm and 17 gpm. We feel that the higher productivity of the Carolina Slate Belt was caused by a greater abundance of permeable openings in the slate belt rocks. These openings included numerous bedding planes within

the laminated argillite, compositional bedding planes between the argillites and volcaniclastic beds, and numerous oblique and vertically dipping joints.

5. The higher incidence of planar openings in the rocks of the Carolina Slate Belt causes these rocks to be more poorly consolidated than the rocks of the other Piedmont metamorphic belts and the igneous rocks also. More than half of the Carolina Slate Belt wells had casing depths which exceeded 100 feet and 36 percent had casing depths of more than 190 feet, while very few of the wells from the other metamorphic belts or igneous rocks had casing depths that exceeded 100 feet. The common occurrence of such poorly consolidated rocks at such depths has only been observed elsewhere in certain fault zones.
6. One hundred and eleven ground water samples were analyzed for hardness, alkalinity, pH, Cl, Mn, Zn, and Cu. In addition, 59 specimens were analyzed for total dissolved solids, 70 Ca determinations were made, and 18 Mg analyses were reported. The values of the chemical parameters of most of the samples were good to excellent with the exceptions of pH, Fe and Mn.
7. With regard to water quality, the principal problem was the low pH. The median value was 6.4, and 25 percent of the samples had pH values below 6.0. The lowest median pH, 5.8, was reported from 9 wells drilled in the Coronaca Granite-Syenite, while the highest value, 7.2, was from the Verdery Gabbro, but only two analyses were reported from this pluton.

A problem of secondary importance was excessive concentrations of iron in 14 percent of the samples and excess manganese in 10 percent of the samples.

8. Two new dolerite dikes were mapped. The first dike, the Shoals Junction Dolerite, begins in northern Greenwood County, and trends N40°W into Abbeville County, a distance of 5 miles. The second one, the Due West Dolerite, was situated about 10 miles SSE of Due West in Abbeville County. Its length was 2.5 miles, while its strike was N34°W. Both dikes dip vertically or nearly so. Magnetometer profiles were made across these two dikes, and on the Easley Dolerite of Pickens County. Studies of these profiles and field mapping suggest that the Shoals Junction Dolerite consists of multiple dikes instead of a single tabular pluton. These multiple dikes were emplaced in extensional fractures which cut across Paleozoic granitic rocks and metamorphic rocks of the Kings Mountain Belt. Unfortunately, no drilled wells were located in the Shoals Junction Dolerite and thus, its ground water capability is not known. Nevertheless, because of the high incidence of fractures here, this zone might well contain good supplies of ground water.

9. Our studies of the data from 7 recently drilled wells situated along the Pax Mountain Fault zone in northern Greenville County, disclosed some interesting and complex problems. One of the wells situated along the axis of this ridge was drilled to a depth of 390 feet. X-ray diffraction studies on the well cuttings showed that this well penetrated poorly consolidated

fault breccia and clay gouge to a depth of 330 feet. This is the deepest occurrence of poorly consolidated rocks known in the Piedmont. Five wells were abandoned here and only two were productive. Three of the wells had to be abandoned because they caved in at a depth of about 260 feet, just when they had encountered prolific amounts of water. Two of the wells were dry holes because the clay gouge had clogged up the void spaces between the coarse breccia particles. The foregoing findings indicate the need for the application of seismic and resistivity studies on fault zones in order to minimize the incidence of expensive nonproductive wells.

Table A1. Data on drilled water wells in Greenwood County, South Carolina.

SCWRC Number	Owner	Use	Driller	Date Drilled	Depth Feet	Depth of Casing	Yield gpm
42-M-q-1	Mt. Carmel Church	Church	Rodgers	-	423	-	8
42-M-q-2	Greenwood State Park, Number 2	Public	-	-	-	-	3
42-M-s-1	" Number 1	"	-	-	-	-	16
42-M-s-2	" "	"	-	-	-	-	15
42-M-u-1	R. Thorpe	Domestic	-	-	-	-	10
42-M-u-2	Panarama Lodge	Business	-	-	-	-	11
42-M-u-3	"	"	-	-	-	-	10
42-M-u-4	Greenwood Shores	Subdivision	-	-	-	-	5
42-M-u-5	"	"	-	-	-	-	5
42-N-b-1	Robert Lewis	Domestic	Rodgers	1976	165	89	25
42-N-c-1	Southern Brick Company	Business	"	1972	305	85	100
42-N-c-2	"	"	-	-	-	-	18
42-N-c-3	"	"	-	-	-	-	18
42-N-c-4	Walter Hill, Jr.	Domestic	Rodgers	1983	130	47	10
42-N-d-1	Sammy German	"	"	1979	263	68	30
42-N-h-1	Pleasant Rock Church	Church	"	1980	183	33	15
42-N-h-2	-	Domestic	"	-	-	-	17
42-N-h-3	"	"	"	1981	100	-	100
42-N-h-4	W. Williams	"	"	1972	230	61	50
42-N-h-5	-	"	"	-	-	-	2
42-N-i-1	Aleane Bonds	"	"	1976	105	71	40
42-O-c-1	Thomas H. Eddy	"	-	1950	100	-	7.5
43-L-p-1	Cothran Subdivision	Subdivision	-	-	-	-	-
43-L-q-1	Lakeland Village	"	-	-	-	-	15
43-L-q-2	-	-	Rodgers	-	165	-	9
43-L-q-3	L. L. Tullis	Subdivision	-	-	-	-	24
43-M-b-1	Kemside Subdivision	"	-	-	-	-	10
43-M-b-2	M.H.P. Fortner (J.E. Fortner)	Trailer Pk.	-	-	-	-	7
43-M-b-3	Irvine's Landing	Business	-	-	-	-	10
43-M-m-1	Curtis Duet Park	Park	-	-	-	-	8

Table A1. Continued

SCWRC Number	Owner	Use	Driller	Date Drilled	Depth Feet	Depth of Casing	Yield gpm
43-M-s-1	Fortner's Subdivision	Subdivision	-	-	-	-	17
43-N-a-1	Paul Lofton	Domestic	Rodgers	1970	444	102	24
43-N-b-1	Dickie Vaughn	"	"	-	-	-	55
43-N-c-1	Starport Country Club	Business	-	-	-	-	19
43-N-l-1	Stanley Vines	Domestic	Rodgers	1980	200	-	12
43-N-l-2	"	"	"	1981	212	-	6
43-N-q-1	Jerral Goudy	"	"	1983	275	-	>10
43-N-u-1	W. D. Bartley	"	"	1979	505	-	5
43-N-u-2	Davey Tree Expert	Business	"	1983	200	-	>10
43-N-u-3	Jack Saxon	Domestic	"	1971	240	-	6
43-N-w-1	Epworth Camp	Business	-	-	-	-	24
43-N-w-2	"	"	-	-	-	-	14
43-N-y-1	Lance Capps	Domestic	Rodgers	1961	146	-	3
43-O-q-1	John Gulledge	"	"	1942	150	-	-
43-O-q-2	L. Richards	"	Warner	1982	180	-	4
43-O-r-1	Dewayne Looper	"	Rodgers	1976	220	-	30
43-O-v-1	B. P. Lamb	"	-	1969	132	-	>10
43-P-c-1	Mountain Creek Baptist Church	Church	Cudd	1957	135	50	12
44-L-f-1	B. Coleman	Domestic	Young	1972	64	40	38
44-L-i-1	Bluff Shores	Subdivision	-	-	-	-	17
44-L-l-1	Sandy Shores Number 1	"	-	-	-	-	14
44-L-o-1	Jack Scurry	Domestic	Rodgers	1971	324	29	17
44-L-o-2	Roger Dorsey	"	"	1979	203	77	10
44-L-o-3	-	"	"	-	450	-	0
44-L-o-4	-	"	"	-	450	-	0
44-L-o-5	-	"	"	-	450	-	0
44-L-o-6	-	"	"	-	450	-	5
44-L-p-1	Tony Roton	"	"	1982	355	158	>100
44-L-p-2	Glen Yonce	"	"	1982	205	80	20
44-L-p-3	Brent Valentine	"	"	1983	130	87	30

Table A1. Continued

SCWRC Number	Owner	Use	Driller	Date Drilled	Depth Feet	Depth of Casing	Yield gpm
44-L-p-4	Gray Moore Jr.	Domestic	Rodgers	1981	203	140	60
44-L-q-1	Robert Smith	"	"	1977	485	90	4
44-L-q-2	"	-	"	1977	305		0
44-L-q-3	Starport GSC	-	Creasman	-	-	-	10
44-L-r-1	John Ward	Domestic	Rodgers	-	255	38	150
44-L-r-2	Atlantic Soft Drink Company	Business	Ruckle	-	-	-	15
44-L-r-3	Harry Quarles	Domestic	Rodgers	1979	145	47	25
44-L-u-1	Stuart's Trailer Park	Trailer Park	-	-	-	-	7
44-L-x-1	Roy Cassel	Domestic	Rodgers	1979	323	63	10
44-M-c-1	Carroll Brooks	"	"	1981	343	84	15
44-M-c-2	Bill Lloyd	"	"	1979	480	71	35
44-M-c-3	Ted Bourne	"	"	1979	540	69	7
44-M-c-4	Ray Burnet	"	"	1970	404	52	4
44-M-c-5	"	-	"	1970	300	-	0
44-M-e-1	James E. Smith	-	"	1977	425	-	0
44-M-e-2	"	Domestic	"	1977	125	75	20
44-M-e-3	Turner Branch (D.S. Allen)	-	-	-	-	-	11
44-M-e-4	Greenwood County Airport	Business	-	-	-	-	15
44-M-f-1	Chastain	Domestic	Rodgers	1964	140	-	12
44-M-h-1	School Bus Maintenance Shop	-	"	-	-	-	0
44-M-h-2	"	Business	"	-	-	-	2
44-M-h-3	H. T. Chandler	Trailer Park	-	-	-	-	11
44-M-h-4	Tanglewood Subdivision	Subdivision	-	-	-	-	17
44-M-m-1	Garner Heights	"	-	-	-	-	19
44-M-m-2	Kateway Water Systems	Business	-	-	-	-	15
44-M-n-1	Stalnaker Heights	Subdivision	-	-	-	-	12
44-M-n-2	"	"	-	-	-	-	11
44-M-p-1	N. Petty	Domestic	Rodgers	-	245	-	22
44-M-u-1	B. T. Mitchell	Trailer Park	-	-	-	-	21
44-M-v-1	Fairforest Subdivision	Subdivision	-	-	-	-	10

Table Al. Continued

SCWRC Number	Owner	Use	Driller	Date Drilled	Depth Feet	Depth of Casing	Yield gpm
44-M-v-2	Fairforest Subdivision	Subdivision	–	–	–	–	10
44-M-v-3	"	"	–	–	–	–	10
44-N-b-1	G. T. Whitman Trailer Park	Trailer Park	–	–	–	–	31
44-N-b-2	E. Hopkins Trailer Park	"	–	–	–	–	3
44-N-c-1	R. C. McDade Mobile Home Park	"	–	–	–	–	14
44-N-d-1	W. J. Inglis Mobile Home Park	"	–	–	–	–	15
44-N-d-2	J. Boyd, Sunrise Circle	Subdivision	–	–	–	–	15
44-N-g-1	Augusta Fields	"	–	–	–	–	10
44-N-g-2	"	"	–	–	–	–	10
44-N-g-3	"	"	–	–	–	–	10
44-N-h-1	Morgen Kizer	Domestic	Rodgers	1972	84	–	15
44-N-h-2	Clark Rivers	"	"	1979	>200	–	17
44-N-h-3	Rodney Case	"	"	1979	260	–	–
44-N-h-4	T. B. Walker	"	"	1963	238	–	–
44-N-h-5	J. W. DeVore Trailer Park	Trailer Park	–	–	–	–	15
44-N-h-6	Utopia Acres Trailer Park	"	–	–	–	–	19
44-N-h-7	Utopia Acres Number 1	Subdivision	–	–	–	–	17
44-N-h-8	Matthews Heights	"	–	–	–	–	4
44-N-h-9	"	"	–	–	–	–	4
44-N-h-10	Auto Drive-In Restaurant	Business	–	–	–	–	10
44-N-i-1	C. J. Hendrix	Domestic	–	1960	70	–	30
44-N-k-1	Norman Capps	"	Rodgers	1974	405	–	8
44-O-c-1	Linda Ammons	"	"	1981	255	161	20
44-O-e-1	James Jackson	"	"	–	140	100	40
44-O-e-2	George Collins	"	"	–	140	–	40
44-O-e-3	Margaret Henderson	"	"	1978	245	125	6
44-O-e-4	G. P. Callison, Jr.	"	"	1982	230	80	100
44-O-e-5	Stallworth	"	"	–	140	–	15
44-O-g-1	Sutherland	"	"	–	220	–	30
44-O-h-1	Frank Townsend	"	Chandler	–	200	160	6

Table A1. Continued

SCWRC Number	Owner	Use	Driller	Date Drilled	Depth Feet	Depth of Casing	Yield gpm
44-O-i-1	James Rodgers	Domestic	Rodgers	1969	125	80	100
44-O-i-2	"	"	"	-	205	191	12
44-O-i-3	"	"	"	1983	240	205	40
44-O-i-4	A. E. Ebert	"	"	-	244	217	40
44-O-1-1	Moses Normany	"	"	1973	85	56	>40
44-O-1-2	J. W. Walker	"	"	1978	145	87	60
44-O-m-1	Leroy Sorrow	"	"	1983	180	83	30
44-O-r-1	Joyce Hines	"	"	1965	450	-	-
44-P-b-1	Andrew Autrey	"	"	1965	160	-	20
44-P-d-1	James Settles	"	"	1979	500	150	2
44-P-e-1	Wayne Brooks	"	"	1983	230	-	30
45-K-b-1	-	-	Chandler	-	300	-	-
45-K-b-2	-	Domestic	Rodgers	-	450	-	30
45-K-w-1	S. Burroughs	"	"	1968	100	-	7
45-K-x-1	Larry Anderson	"	"	1983	>300	-	5
45-K-x-2	Maurice Anderson	"	"	1981	303	78	30
45-K-y-1	Walnut Grove Church	Church	"	1977	285	39	7
45-L-c-1	W. S. Burroughs	Domestic	"	1978	285	80	>25
45-L-c-2	J. Smith	"	"	1977	225	-	35
45-L-d-1	Tommy Hammond	"	"	1981	230	93	7
45-L-h-1	Ed Frye	Subdivision	"	1976	365	48	22
45-L-h-2	"	"	"	1976	300	-	0
45-L-h-3	"	"	"	1976	300	-	0
45-L-h-4	"	"	"	-	400	42	50
45-L-k-1	Paul Wash	Domestic	"	1976	125	70	60
45-L-k-2	J. B. Adams	"	"	1982	280	-	5
45-L-p-1	Otis H. Harvey	Business	Cudd	1968	145	40	10
45-L-p-2	Catherine Davis	Domestic	Rodgers	-	300	0	0
45-L-p-3	"	"	"	-	145	84	100
45-L-o-1	H. Cobb	"	Cudd	1968	285	-	3

Table A1. Continued

SCWRC Number	Owner	Use	Driller	Date Drilled	Depth Feet	Depth of Casing	Yield gpm
45-L-q-1	L. Powell	Domestic	Rodgers	1978	345	71	6
45-L-s-1	Park Seed Company	Business	-	-	-	-	13
45-L-s-2	"	"	-	-	-	-	13
45-L-s-3	"	"	-	-	-	-	13
45-L-s-4	J. A. Wilson	Domestic	Newberry	1975	150	82	7
45-L-t-1	Mike Smith	"	Rodgers	-	245	152	14
45-L-u-1	C. Canincia	"	"	1979	423	50	20
45-L-u-2	Eddie Lloyd	"	"	-	-	-	>100
45-L-u-3	David Brooks	"	"	1975	105	63	>60
45-L-v-1	Northfall Acres	Subdivision	-	-	-	-	17
45-L-x-1	Greenwood Memorial Gardens	Irrigation	Rodgers	-	500	82	25
45-L-x-2	Glover Wood	Domestic	"	1970	155	45	7
45-L-x-3	John Barrett	Business	"	1970	151	-	7
45-L-y-1	Gary Sharkey	Domestic	"	1981	255	92	9
45-L-y-2	Highland Mobile Home Park	Trailer Park	-	-	-	-	15
45-M-c-1	Calvary Baptist Church	Church	Cudd	1970	-	-	50
45-M-c-2	Kaye Subdivision	Subdivision	-	-	-	-	19
45-M-c-3	"	"	-	-	-	-	19
45-M-c-4	LaPorte Subdivision	"	-	-	-	-	14
45-M-c-5	Hyde Park Subdivision	"	-	-	-	-	18
45-M-c-6	"	"	-	-	-	-	18
45-M-c-7	"	"	-	-	-	-	18
45-M-c-8	"	"	-	-	-	-	18
45-M-d-1	Dalewood Subdivision	"	-	-	-	-	24
45-M-d-2	Windemere Subdivision	"	-	-	-	-	15
45-M-d-3	"	"	-	-	-	-	15
45-M-e-1	Ed Brown	Domestic	Rodgers	1978	205	74	15
45-M-f-1	C. H. Butler	"	"	1982	155	43	30
45-M-n-1	Westridge Subdivision	Subdivision	-	-	-	-	12
45-M-n-2	Lakewood Heights	"	-	-	-	-	18

Table A1. Continued

SCWRC Number	Owner	Use	Driller	Date Drilled	Depth Feet	Depth of Casing	Yield gpm
45-M-q-1	Westgate Water Company	Business	-	-	-	-	31
45-M-q-2	Woodlawn Subdivision	Subdivision	-	-	-	-	24
45-M-q-3	"	"	-	-	-	-	24
45-M-r-1	Timberlake Subdivision	"	-	-	-	-	17
45-M-r-2	Rosemont Subdivision	"	-	-	-	-	15
45-M-r-3	Westover Water Company	Business	-	-	-	-	29
45-M-r-4	"	"	-	-	-	-	29
45-M-r-5	"	"	-	-	-	-	29
45-M-x-1	McComb's Subdivision	Subdivision	-	-	-	-	37
45-N-c-1	Rick's BBQ	Business	-	-	-	-	7
45-N-d-1	D. Latham	Domestic	Rodgers	1977	225		6
45-N-f-1	Promised Subdivision	Subdivision	-	-	-	-	23
45-N-f-2	"	"	-	-	-	-	23
45-N-l-1	Harless - Seymour Subdivision	"	-	-	-	-	19
45-N-o-1	Promised Land Heights	"	-	-	-	-	15
45-N-p-1	Harold Creswell	Domestic	Rodgers	1960	-	-	15
45-O-f-1	Doug Goldman	"	"	1976	145	89	25
45-O-f-2	C. M. Tuck	"	"	1966	155	-	11
45-O-h-1	W. D. Goldman	"	"	1976	285	104	5
45-O-o-1	Dewey Outz	"	"	1974	365	153	15
45-O-o-2	Richard N. James	"	-	1974	180	-	>10
45-P-a-1	Carl Arnold	"	Rodgers	1982	250	202	50
45-P-b-1	J. Bannister	"	"	-	505	204	7
46-K-v-1	B. P. Robinson	"	-	1976	180	-	40
46-L-b-1	George M. Swansey	"	Coleman	1972	210	-	30
46-L-c-1	Frank N. Smith	"	"	1978	200	200	4.5
46-L-d-1	Jerry V. Davis	"	Rodgers	1974	200	-	-
46-L-r-1	Jack Thompson	Irrigation	Cudd	1981	533	-	-
46-L-v-1	-	Domestic	-	1963	-	-	-
46-O-u-1	James Harrison	"	Rodgers	1982	605	82	2

Table A1. Continued

SCWRC Number	Owner	Use	Driller	Date Drilled	Depth Feet	Depth of Casing	Yield gpm
46-P-d-1	Doris McCaslan	Domestic	Rodgers	1978	125	92	30
46-P-d-2	Charles Creswell	"	"	-	125	92	30
46-P-h-1	Randy Young	"	"	1977	505	142	3
46-P-h-2	Etta White	"	"	1982	230	51	20

Table A2. Chemical data on selected wells in Greenwood County, South Carolina.

SCWRC Number	Type of Well	TDS	Hardness	pH	Alkalinity	Cl	Ca	Mg	Fe	Mn	Zn	Cu	Rock Type
42-M-q-2	D	250	120	7.5	151	14	31	–	.1	<.05	<.05	<.05	Charlotte Belt
42-M-q-3	D	90	36	6.4	47	2	9	3.2	<.1	<.05	.7	<.05	"
42-M-u-4	D	–	86	6.4	80	19.5	20	–	<.1	<.05	.11	<.05	"
42-M-u-6	D	–	65	6.7	86	4	10	–	.1	<.05	.8	<.1	"
42-M-w-1	D	310	86	6.2	71	6	–	–	6.0	.13	.3	.1	"
42-N-c-1	D	–	460	7.8	147	4	30	–	.1	.12	.1	<.05	"
42-N-k-1	B	130	50	6.0	55	1	10	–	<.1	<.05	<.1	<.1	Carolina Slate Belt
42-O-f-1	B	35	<20	5.7	13	5	–	–	<.1	<.05	<.1	.2	Greenwood Pluton
43-L-p-1	D	–	22	5.1	34	3	9	–	.2	<.05	.37	.07	Coronaca Granite Syenite
43-L-q-1	D	–	40	6.0	54	6	13	–	.2	<.05	.07	<.05	"
43-L-q-4	D	–	34	5.6	42	7	10	–	<.1	<.05	<.05	.07	Charlotte Belt
43-L-q-5	D	–	20	5.6	33	4	6	–	1.6	<.05	.08	<.05	"
43-L-q-6	D	86	17	5.1	29	4	–	–	<.05	<.05	.21	4.5	"
43-M-b-1	D	–	53	6.0	70	4	14	–	<.1	<.05	.1	.13	"
43-M-b-2	D	–	36	5.7	33	4	6	–	<.1	<.05	<.1	<.1	"
43-M-m-1	D	–	36	5.6	22	9.5	8	–	<.1	<.05	<.1	<.1	"
43-M-q-1	HD	100	27	6.1	42	4	7	2.3	3.0	.07	.15	.22	"
43-M-s-1	D	–	29	5.6	25	4.5	6	–	<.1	<.05	.1	.4	"
43-N-j-1	HD	200	26	6.3	33	4	–	–	3.0	<.05	.3	1.0	Greenwood Pluton
43-N-o-1	B	80	14	6.4	18	3	3.8	1.0	.05	<.05	<.05	<.05	"
43-N-q-1	D	1500	41	7.6	42	5	16	.35	<.05	<.05	<.05	<.05	"
43-N-u-2	D	130	60	7.1	72	4	15	5.4	.3	<.05	1.5	.35	"
43-N-u-3	D	126	43	7.1	55	1.5	10	4.3	<.05	<.05	.62	<.05	"
43-O-i-1	D	160	70	6.1	88	14	–	–	.2	<.05	10.0	<.1	"
43-O-i-2	B	112	42	6.5	49	9	15	1.0	.06	<.05	.42	.07	Charlotte Belt
43-O-q-1	D	230	75	6.0	32	40	–	–	.1	<.05	.31	<.05	Carolina Slate Belt
43-O-q-2	D	76	20	6.5	28	4	5	1.9	.06	<.05	.39	<.05	"
43-P-c-1	D	136	77	7.5	95	3	–	–	4.3	<.05	.2	<.1	"
44-L-f-1	D	–	10	5.9	27	–	–	–	<.1	<.05	.8	<.1	Mulberry Creek Granite
44-L-i-1	D	–	140	6.2	124	4	30	–	.4	.15	.2	<.1	Kings Mountain Belt
44-L-l-1	D	–	150	6.6	70	29	200	–	<.1	.06	.2	<.1	"

Table A2. Continued

SCWRC Number	Type of Well	TDS	Hardness	pH	Alkalinity	Cl	Ca	Mg	Fe	Mn	Zn	Cu	Rock Type
44-L-o-2	D	190	74	6.5	100	14	–	–	1.5	<.05	.29	.06	Kings Mountain Belt
44-L-p-1	D	1200	800	7.4	56	–	–	–	.1	<.05	.19	<.05	"
44-L-r-3	D	110	27	6.6	54	5	–	–	<.1	<.05	.3	<.1	"
44-L-r-4	HD	150	43	6.2	37	16	–	–	<.1	<.05	.1	<.1	"
44-L-r-5	HD	130	58	6.4	43	20	–	–	<.1	<.05	.2	<.1	"
44-L-u-1	D	–	26	5.2	9	4.5	3	–	<.1	<.05	<.1	<.1	Coronaca Granite Syenite
44-L-u-4	D	110	28	5.8	24	19	–	–	<.1	<.05	<.05	.46	"
44-L-w-1	D	120	51	6.3	78	6.5	9	7	1.8	.5	.11	<.05	Mulberry Creek Granite
44-M-e-3	D	–	120	6.6	91	3.5	60	–	.1	<.05	.8	<.1	Charlotte Belt
44-M-e-4	D	100	14	6.6	22	2.5	–	–	.1	<.05	.5	1.0	Coronaca Granite Syenite
44-M-h-3	D	–	25	5.4	16	3.5	3	–	.9	<.05	.1	<.1	"
44-M-m-1	D	–	34	6.7	24	3.5	4	–	<.1	<.05	.08	<.05	"
44-M-m-2	D	–	37	6.6	29	4.5	5	–	<.1	<.05	.05	<.05	"
44-M-n-1	D	–	22	5.2	24	6.5	8	–	<.1	<.05	<.05	<.05	"
44-M-p-1	D	116	38	6.6	58	7.0	–	–	.1	<.05	3.0	<.1	Charlotte Belt
44-M-u-1	D	–	48	7.0	47	4.0	8	–	<.1	<.05	.06	<.05	"
44-M-v-1	D	–	40	6.2	42	2.5	8	–	<.1	<.05	<.1	.1	"
44-M-y-1	D	58	62	6.8	41	3.5	20	3	.2	<.05	<.05	<.05	"
44-N-a-1	HD	110	110	6.4	69	8.5	–	–	.2	<.05	.9	<.1	"
44-N-b-1	D	–	44	6.4	41	4.5	1	–	<.1	<.05	.2	<.1	"
44-N-b-2	D	–	41	6.6	31	3	6	–	.4	<.05	.38	<.05	"
44-N-b-3	D	40	20	5.6	30	1.5	–	–	<.1	<.05	.4	<.1	"
44-N-c-1	D	–	47	7.3	39	5	8	–	<.1	<.05	.05	<.05	"
44-N-d-1	D	–	25	5.8	41	2.5	9	–	<.1	<.05	.48	<.05	"
44-N-d-2	D	–	16	5.6	24	3.5	7	–	<.1	<.05	.22	<.1	"
44-N-h-5	D	–	55	7.1	53	2.3	8	–	.1	<.05	.08	<.05	"
44-N-h-6	D	–	46	6.0	39	3	8	–	<.1	<.05	.2	<.1	"
44-N-h-7	D	–	72	7.4	81	4	10	–	<.1	<.05	.47	<.05	"
44-N-h-8	D	–	40	5.8	37	4.5	9	–	<.1	<.05	.1	<.1	"
44-N-m-1	D	220	33	5.8	37	3.5	–	–	3.0	.07	2.0	<.1	"
44-O-f-1	D	110	24	7.2	43	2.5	–	–	.2	<.05	<.05	<.05	"

Table A2. Continued

SCWRC Number	Type of Well	TDS	Hardness	pH	Alkalinity	Cl	Ca	Mg	Fe	Mn	Zn	Cu	Rock Type
45-L-k-2	D	110	16	6.3	37	4	-	-	<.1	<.05	8.0	.1	Kings Mountain Belt
45-L-n-1	B	90	27	6.2	27	19	7.5	2	<.1	<.05	.1	.8	Mulberry Creek Granite
45-L-o-1	D	78	24	6.3	37	4.5	6	2.2	<.1	<.05	2.5	.07	Charlotte Belt
45-L-o-2	HD	90	14	5.0	10	3.5	-	-	<.1	<.05	<.05	<.05	Mulberry Cr. Gr Myl
45-L-p-1	D	110	22	6.5	29	8	-	-	<.1	<.05	.19	<.05	"
45-L-q-1	D	550	290	7.1	53	2.5	-	-	<.1	<.05	<.05	<.05	Kings Mountain Belt
45-L-s-4	D	92	13	6.5	22	6	-	-	<.1	<.05	<.1	<.1	"
45-L-u-1	D	8.8	37	6.5	49	2	-	-	<.1	<.05	.15	.07	Charlotte Belt
45-L-v-1	D	-	120	7.1	85	3.5	80	-	<.1	<.05	.5	<.1	"
45-L-x-4	HD	56	30	5.8	27	.5	-	-	2.0	<.05	.1	<.1	Kings Mountain Belt
45-L-y-1	D	230	74	7.8	88	2.5	-	-	<.1	<.05	.16	<.05	Charlotte Belt
45-L-y-2	D	-	40	5.9	27	3	6	-	<.1	<.05	<.05	<.05	"
45-M-c-2	D	-	42	7.0	36	3	6	-	<.1	<.05	.06	<.05	Kings Mountain Belt
45-M-c-4	D	-	47	6.6	44	2.5	7	-	.4	<.05	<.05	<.05	"
45-M-c-5	D	-	40	6.7	37	3	6	-	.1	<.05	<.05	<.05	Charlotte Belt
45-M-d-1	D	-	26	5.6	31	3.5	7	-	<.1	<.05	.1	<.05	"
45-M-d-2	D	-	57	6.0	54	6	10	-	<.1	<.05	<.1	<.1	Kings Mountain Belt
45-M-d-3	D	-	43	6.0	44	3.9	9	-	<.1	<.05	.3	<.1	"
45-M-f-1	D	100	46	6.6	75	-	-	2	.29	.14	.12	<.05	"
45-M-j-1	D	94	21	6.7	36	2.5	-	-	<.1	<.05	.6	<.1	Charlotte Belt
45-M-j-2	D	74	20	6.2	24	2.5	-	-	<.1	<.05	.1	.2	"
45-M-n-1	D	-	35	7.1	31	3.5	4	-	<.1	<.05	.21	<.05	"
45-M-n-2	D	-	35	6.4	35	2.5	5	-	<.1	<.05	<.05	.08	"
45-M-q-1	D	-	44	6.7	34	4	7	-	<.1	<.05	<.05	.32	"
45-M-q-2	D	-	35	6.8	23	3.5	3	-	<.1	<.05	<.05	1.4	"
45-M-q-4	HD	72	13	6.2	27	3	-	-	<.1	<.05	<.1	.1	"
45-M-r-1	D	-	44	6.5	43	4	7	-	<.1	<.05	<.05	<.05	"
45-M-r-2	D	-	41	6.4	26	3.5	5	-	<.1	<.05	.06	.22	"
45-M-r-3	D	-	48	5.6	44	7	.4	-	<.1	<.05	.4	.2	"
45-M-r-6	D	130	68	7.0	93	2	-	-	1.1	.11	.5	<.1	"
45-M-w-1	D	-	28	5.3	39	4.5	9	-	<.1	<.05	<.05	.33	"

Table A2. Continued

SCWRC Number	Type of Well	TDS	Hardness	pH	Alkalinity	Cl	Ca	Mg	Fe	Mn	Zn	Cu	Rock Type
45-M-x-1	D	-	27	5.2	20	4	4	-	<.1	<.05	.1	.1	Charlotte Belt
45-N-c-2	D	100	27	6.8	43	2.5	-	-	<.1	<.05	<.05	<.05	"
45-N-e-1	B	110	36	6.2	51	5	-	-	1.3	<.05	.8	<.05	"
45-N-f-1	D	-	21	6.2	30	2.5	7	-	<.1	<.05	.14	<.05	"
45-N-h-1	HD	64	24	6.4	35	5	-	-	<.1	<.05	<.1	<.1	"
45-N-1-1	D	-	38	6.8	29	3	5	-	<.1	<.05	.06	.09	"
45-N-o-1	D	-	43	6.2	50	3	10	-	<.1	<.05	<.1	<.1	"
45-N-p-2	B	86	22	5.9	46	9	20	1.6	<.1	<.05	<.1	.2	"
45-N-q-1	D	140	78	7.2	57	2	-	-	.1	<.05	.1	<.1	Verdery Gabbro
45-O-f-2	D	86	40	7.2	58	2.5	9	4.2	<.05	<.05	.8	<.05	Charlotte Belt
45-O-n-1	B	130	56	7.3	79	5	-	-	.1	<.05	.4	<.1	Verdery Gabbro
46-K-r-1	B	130	71	6.8	52	18.5	20	5	.07	<.05	.47	.05	Kings Mountain Belt
46-K-v-1	D	96	37	7.5	56	2	10	2.9	<.05	<.05	.8	<.05	Kings Mtn./Shoals Junct
46-K-v-2	B	106	34	6.8	45	3	13	.39	2.5	.08	.05	.14	"
46-L-j-1	HD	72	<20	4.8	4	13.5	-	-	.1	<.05	<.1	<.1	"
46-L-m-1	D	1000	895	7.4	56	2.7	-	-	.5	.08	.1	<.1	"
46-N-s-1	D	140	27	6.6	42	15	-	-	1.1	<.05	<.1	<.1	Charlotte Belt
46-P-c-1	B	-	160	6.9	133	12	-	-	<.1	<.05	<.1	<.1	"

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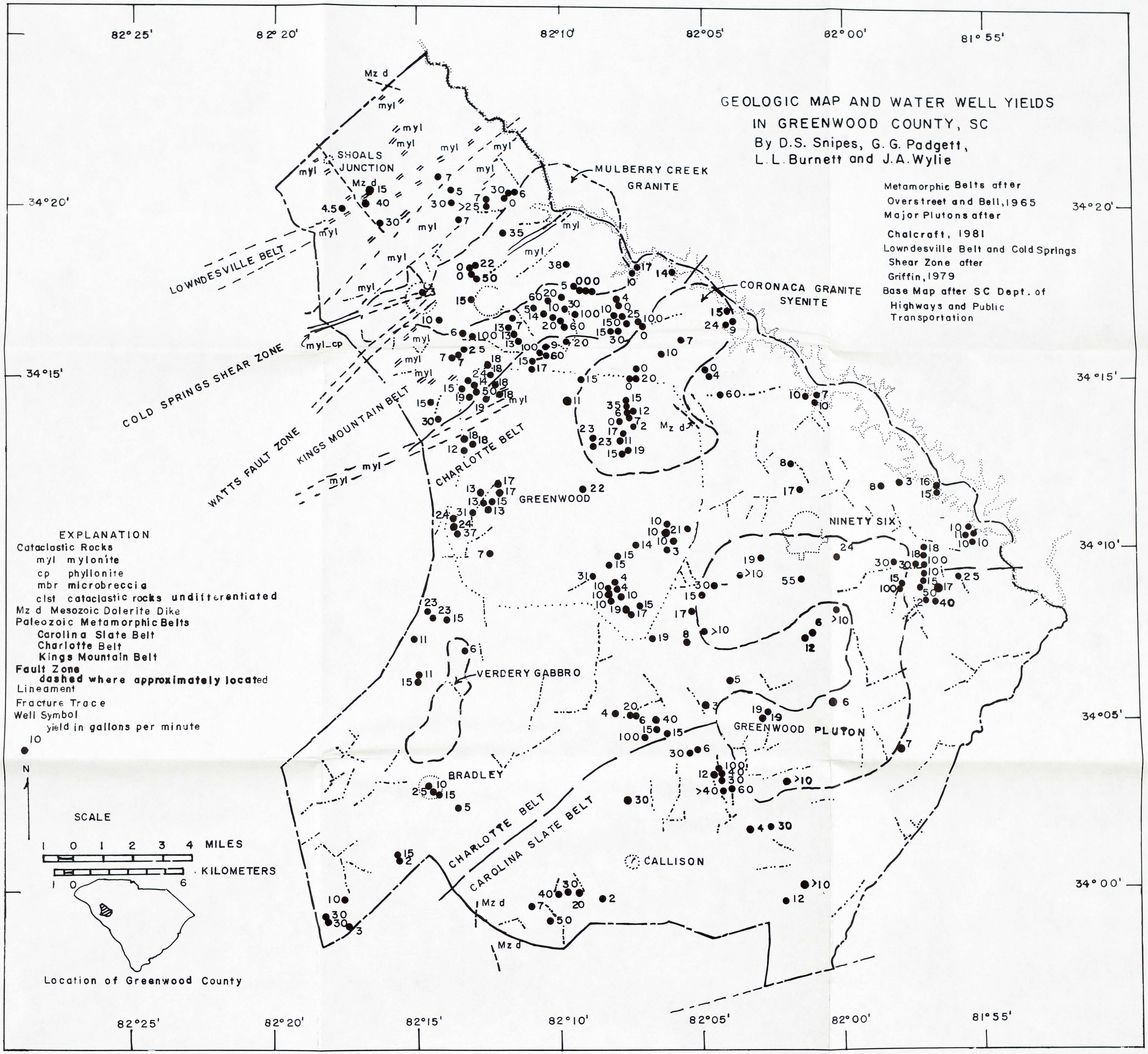

Figure 2. Geologic map and water well yields in Greenwood County, South Carolina.