GEOLOGIC NOTES

DIVISION OF GEOLOGY
STATE DEVELOPMENT BOARD
COLUMBIA, S. C.

NOVEMBER 1965

Volume 9

Number 3

GEOLOGIC NOTES

Volume 9 | November 1965 | Number 3

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SLUMP FEATURES IN THE McBEAN FORMATION AND YOUNGER BEDS, RILEY CUT, CALHOUN COUNTY, SOUTH CAROLINA

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ABSTRACT

The Riley Cut is located about five miles to the northwest of the Orangeburg Scarp in the upper Coastal Plain of South Carolina. The Eocene McBean Formation and younger (Miocene?) terrace sediments are exposed in a series of semi-symmetrical open-fold anticlines and synclines on the order of 75 to 200 feet across. Fractures and small faults are associated with the folds. Clastic dikes have filled some of the fractures and faults. A lower mottled zone reflects the form of the folds and developed before the folds. An upper mottled zone only partly reflects the form of the folds. Both mottled zones are interpreted as paleosols.

The folds probably formed as a result of the uneven letdown of beds in response to a differential removal of calcium carbonate from the underlying McBean Formation or possibly Santee Limestone.

INTRODUCTION

A cut on the Southern Railroad, 0.4 mile NNE of Bench Mark 324 at Riley, South Carolina, and 2.6 miles SSW of the center of St. Matthews, exposes an interesting sequence of marine Eocene beds and younger terrace sediments. This section has been studied in detail because it illustrates some of the problems of Coastal Plain stratigraphy, weathering, and structure.

The Riley Cut is located in the upper Coastal Plain about five miles to the northwest of the Orangeburg (Citronelle) Scarp (Doering, 1960; Colquhoun, 1962, p. 68; 1965, p. 19), a Miocene (?) shoreline feature. The upper Coastal Plain (northwest of the Scarp) is a dissected rolling terrain underlain by gently dipping Cretaceous and Eocene sediments. Non-marine older terrace units cap most of the hills to a maximum thickness of 20 to 30 feet. Southeast of the Scarp the lower Coastal Plain is flat and undissected. It is underlain by Eocene and Oligocene limestones and younger carbonate and clastic rocks of Miocene-Pleistocene age.

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Slump structures have been described in the Cretaceous Middendorf Formation (Heron, 1959), and the Eocene Black Mingo Formation of the upper Coastal Plain (Heron and Johnson, 1963). Topographic depressions (unrelated to Carolina Bays) are present in the outcrop area of the Warley Hill Formation in Calhoun and Orangeburg Counties.

LOCAL STRATIGRAPHY

The middle Eocene McBean Formation and Miocene(?) (Colquhoun, 1962, p. 74) terrace sediments form the exposed rocks in and near the Riley Cut, elevation about 330'. About 1 mile to the northeast the Warley Hill Formation is known to underlie the McBean Formation, the contact being at approximately 213' elevation (Figure 1). Three and one-half miles to the southeast the McBean Formation is underlain by the Santee Limestone. The general lithologies of each of these units is described in the auger hole logs of Fig. 1 and Fig. 2.

The general stratigraphic relations of the Santee, Warley Hill, and McBean Formations have been described by Pooser (1965). He has found the Warley Hill to be a quartzose, glauconitic, and calcareous unit that underlies, grades upward into, and intertongues with the Santee Limestone. The Santee Limestone is of middle Eocene age in the vicinity of the Riley Cut. The McBean Formation unconformably overlies the Santee Limestone northwest of the Orangeburg Scarp but it is absent southeast of the Scarp, apparently having been cut out by the Miocene(?) transgression that formed the scarp. Pooser (p. 19) believes that the McBean Formation is the near-shore facies of part of the downdip Santee Limestone.

SLUMP FEATURES

Sedimentary Units

Seven sedimentary units can be recognized in the Riley Cut (Figure 3). Units 1-5 are typical of the McBean Formation. Unit 7 is typical of the terrace deposits northwest of the Orangeburg Scarp. Unit 6 may be part of the McBean Formation or it may be another terrace unit. The bedding within each unit is poorly to moderately well developed, but the contacts between the units are usually sharp and serve to outline the structures. The basal contacts of units 6 and 7 appear to be unconformities.

Structures

A series of semi-symmetrical open-fold anticlines and synclines are clearly outlined by the contacts between the sedimentary units. The folds are on the order of 75 to 200 feet across.

Various fractures and small faults are associated with the folds. The fractures may in part have a dual origin. Most fractures were form-

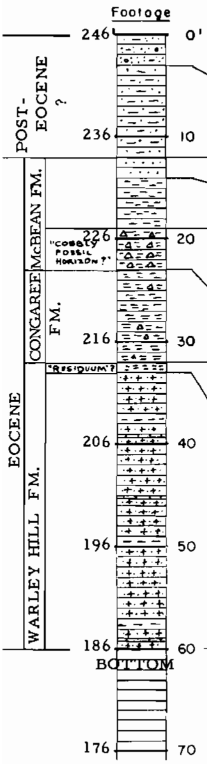
DRILL HOLE LOG — CALHOUN COUNTY

Drill hole: CALHOUN #19 (power auger hole) Date: May 28, 1962 Total depth: 60'

Location: NE 1/4 St. Matthews 15' quad.; on edge of U.S. 601, 1.4 mi. SSW of center of St. Matthews.

Collar elevation · 246' (altimeter) Logged by: Henry S. Johnson, Jr.

Drilled by: Division of Geology, S. C. State Development Board



Description

0-3': Sand, F, slightly clayey, dark brown to light yellow brown; soil; contains sparse rounded quartz pebbles to 1 inch in diameter.

3-12': Sand, C, clayey to very clayey, red in upper portion becoming red brown downward; very tough drilling at 600-800 lbs. pressure.

12-14': Sand, F, golden.

14-19': Clay, silty, semiplastic, yellow brown with greenish tint; very tough drilling at 600-800 lbs. pressure.

19-23': Chert(?) nodules or pebbles, up to 1 1/2 inches in diameter, creamy yellow to white, in matrix of dark brown silty clay; drills with crunchy feel.

23-32': Clay, silty, dark brown; contains sparse fragments of creamy yellow to white chert (?) (possibly contamination from Unit 19-23').

32-33': Clay, plastic, glauconitic, brownish black; drill dropped almost as if in a cavity.

33-60': Sand, glauconite, F-M, slightly clayey to very clayey, yellow green to dark green; slightly calcareous in part; contains occasional thin layers (1-2 inches thick) of green non-calcareous clay and white hard limestone seams.

Bottom at 60'.

Remarks:
Water table at about 35'.

Figure 1. Drill hole log - Calhoun County, South Carolina

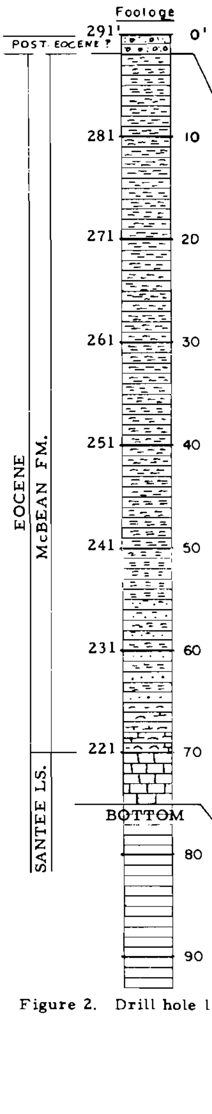
DRILL HOLE LOG — CALHOUN COUNTY

Drill hole: CALHOUN #12 Date: May 3, 1962 Total depth: 75'

Location: SE 1/4 St. Matthews 15' quad. ; on County Road 45 at junction 291, 2.8 mi. N 80° E of Jamison.

Collar elevation: 291' (spot elevation) Logged by: Henry S. Johnson, Jr.

Drilled by: Division of Geology, S. C. State Development Board



Description

0-2': Sand, F-VC, and conglomerate, light gray to reddish brown; a veneer that blankets the surface over hills and valleys in this area; contains rounded quartz pebbles to 3 inches in diam.

2-70': Clay, silty; red to 24', yellow brown 24-45', pale green 45-70'; contains thin interbedded (?) M-C sands from 55' to 65' but is predominantly silty clay; lower five feet is moderately to slightly calcareous and contains yellow white chert fragments up to 1/4 inch in diam. ; Turritella sp. and large pelecypod fragments in 65-70' range.

70-75': Limestone, gritty, creamy white; contains sparse M-C quartz grains and white chert (?) fragments to 1/4 inch in diam. ; contains sparse pelecypod (?) fragments; very calcareous; non-glauconitic; drills with crunchy feel.

Bottom at 75' in limestone.

Remarks:

Water table at 24'.

The 65-70' interval here may be the equivalent of the "cobbly fossil zone" that is present at the base of the McBean Fm. over the area to the north and west.

Figure 2. Drill hole log - Calhoun County, South Carolina

ed during the period of fold development. Some fractures may be associated with the formation of mottled zones I or II, that is, a product of volume changes produced by soil forming processes. In any event most fractures are bleached, probably as a result of local reduction of iron oxide by ground water moving downward along the fracture zones.

Gravity faults with a maximum offset of about 18 inches are found at the 170, 190, and 535 foot marks (Figure 3). The fault at the 535 foot mark is also occupied by a clastic dike. One small thrust fault can be seen at the 340 foot mark (Figure 3). The apparent displacement on this fault is about 4 inches.

Mottled Zones

Two separate and distinct mottled zones can be seen in the Riley cut. Mottled zone I is developed in unit 6 and to some extent in unit 5. This mottling is strongly oriented normal to the bedding. Such a "picket fence" type of structure has been observed in the "purple-white" mottling at or immediately above the top of the Moenkopi Formation in the San Rafael Swell (Johnson, 1957, p 44). It is generally accepted as due to soil forming processes and where unrelated to the present ground surface is considered a paleosol (Johnson, 1957; Schultz, 1963; Johnson, 1964).

The "picket fence" structure of mottled zone I was tilted by the folding and so must have developed before slumping.

Mottled zone II is developed in part of unit 7. The mottling is not as strongly oriented as in mottled zone I but does appear to be somewhat tilted and downwarped, thus indicating some additional slumping after formation of the paleosol.

Clastic Dikes

Clastic dikes similar to those described by Heron, Johnson, and Pooser (1965) are well developed in the Riley Cut. One of the dikes has filled a fault (Figure 3, 535 foot mark) but most others have filled fractures developed as a result of the slumping or as a result of the soil forming processes that formed the mottling.

Sequence of Events

The following sequence of events has been deduced from the Riley Cut:

1. Deposition of McBean Formation, units 1-5.
2. Unconformity (Local?).
3. Deposition of unit 6, probably McBean Formation.
4. Uplift, erosion, and development of paleosol in unit 6 including formation of vertical "picket fence" type of mottling (mottled zone I) below unit 6a. Unit 6a may represent the A horizon associated with the underlying B mottled zone. A few scattered pebbles at the base of unit 6a could signify

local transportation during the time of soil formation. An alternate interpretation is that unit 6a is a separate sedimentation unit deposited after the weathering of unit 6.

5. Partial collapse of units 1-6 with formation of fractures.
6. Further weathering and bleaching of fractures and erosion (unconformity).
7. Deposition of unit 7.
8. Additional collapse with formation of larger and longer clastic dikes and other fractures. Concurrent weathering resulted in the formation of a soil profile on unit 7 including the formation of a B horizon, mottled zone II. Slight collapse continues.
9. Erosion and formation of present surface.

Genesis of Slumping

The folds in the Riley Cut have formed as a result of the uneven letdown of the beds; that is, they are slump features. This is verified by (1) the lack of any regional extent to the folding; (2) the tilting of the mottled zones ("picket fence" structure) in accordance with the underlying folds, thus indicating that the folds are essentially features of the surface; (3) the presence of fractures and faults oriented and displaced so as to suggest formation as a result of letdown of the beds beneath the synclines (fractures tilt toward the synclines). The small thrust fault is no exception as it probably represents slight horizontal adjustment of unit 6 as it was let down into the adjacent syncline.

The anticlines were formed passively as a result of the slow dropping down of beds on either side into adjacent synclines. The slumping is probably caused by removal of calcium carbonate by solution in ground water. That the areas of solution were irregular is suggested by the lack of periodicity of the folds.

Pooser (1965, p. 19) has recognized the presence of "light weight" siltstones in the area where the McBean Formation overlies the Santee Limestone. Pooser attributes these siltstones to "the Santee Limestone that was incorporated within the basal McBean, but has subsequently been leached of its calcium carbonate content" (p. 19). The McBean is not now characteristically calcareous in South Carolina although it is highly calcareous in the type section in Georgia. Most of the calcium carbonate originally present in the McBean in South Carolina has been removed by solution or locally replaced by silica.

Tongues of typical Santee Limestone are also present at a depth of about 70 to 90 feet in the general area of the Riley Cut. Slumps due to leaching and collapse of this unit are conceivable but in view of the depth involved would seem likely to be more subdued than the folds seen in the Riley Cut.

Other conceivable ways in which the slumps could have formed include (1) by volume changes associated with solution of opal (Heron and Johnson, 1963), traces of which are known to be present in the McBean

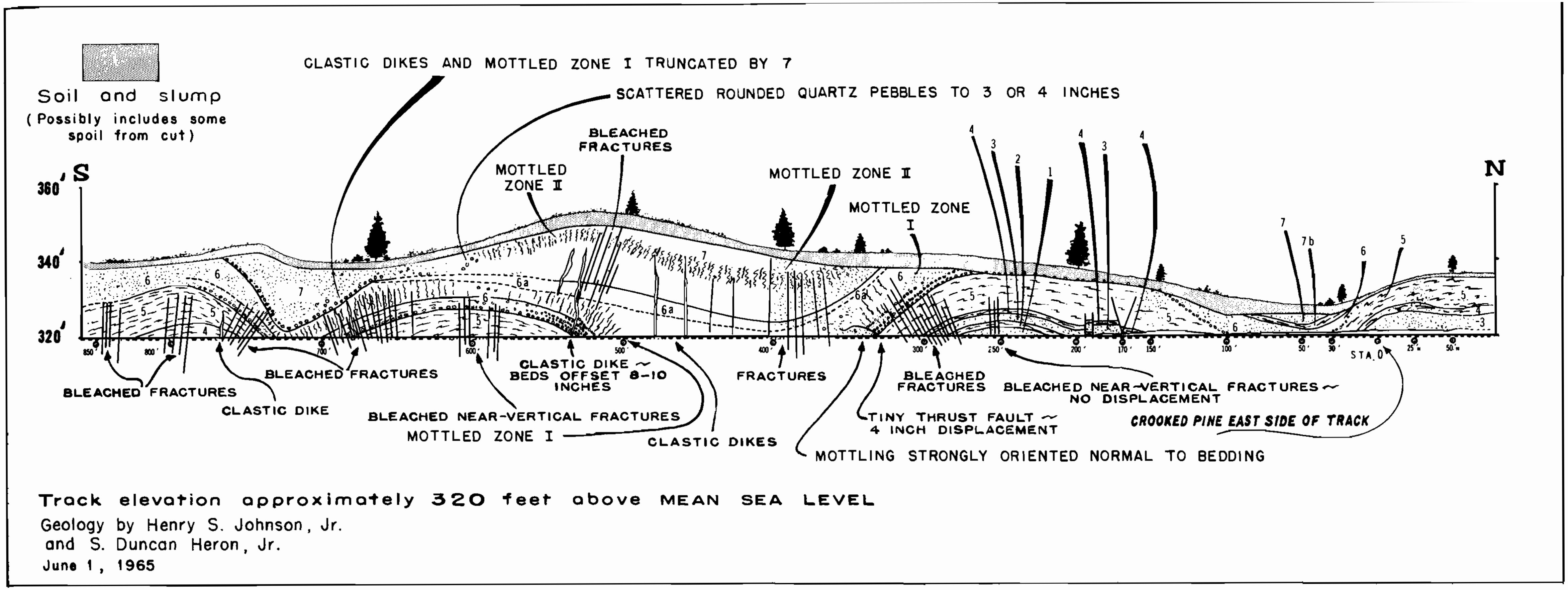


Figure 3. Locality 9-66, the Riley Cut.

EXPLANATION OF SECTION

Miocene (?)

7. Sand, fine to very coarse, mottled pink and red; sparse rounded quartz pebbles up to 1/2 inch, locally abundant near base.

7b. Sand, fine to very coarse, clayey, mottled pink and red.

Unconformity

Eocene (?)

McBean Formation (?)

6a. Sand, very fine to fine, pinkish; locally slightly clayey; scattered sparse small rounded quartz pebbles.

6. Sand, fine up to very coarse, very light yellow brown with gray-white mottling; locally clayey; sparse rounded quartz pebbles up to 4 inches with local concentration of quartz pebbles and coarse sand at or near base.

Unconformity

Eocene

McBean Formation

5. Sand, fine to coarse, clayey, mottled pink, orange, red, grey, and yellowish green; sparse (5%) weathered feldspar grains common near base; irregular blebs of clay interpreted as clayey layers disturbed by boring organism.

4. Silt, clayey, slightly micaceous, light greenish gray with orange and red mottles.

3. Sand, very fine to medium, silty, slightly clayey, slightly micaceous, gray with greenish tint.

2. Silt, very clayey, purple with red and pink mottling; contains sand blebs and irregular layers interpreted as disturbed by boring organisms.

1. Sand, very fine, clayey, micaceous, yellowish green.

Formation (Heron, Robinson, and Johnson, 1965, p. 24); (2) differential compaction of the McBean Formation, which is clay rich in this area; and (3) by plastic deformation of the clay rich McBean.

CONCLUSIONS

(1) Slumping similar to that in the Riley Cut is a common upper Coastal Plain phenomenon. In South Carolina it has been seen in the Cretaceous Middendorf Formation (Heron, 1959), the lower Eocene Black Mingo Formation (Heron and Johnson, 1963), the McBean Formation (this paper), and in the Warley Hill Formation outcrop area.

(2) The Riley Cut and many nearby exposures show that the "Citronelle Formation" of Doering (1960) is seldom over 20 feet thick in South Carolina.

(3) There are several periods of paleosol formation in this area. The oldest corresponds to the time interval after deposition of the Eocene beds and before deposition of the Miocene (?) terrace deposit. The youngest paleosol formed in the time interval after deposition of the terrace deposit and before the formation of the present surface.

(4) The clastic dikes so common in this part of South Carolina can be (a) associated with the formation of the soil profile and, (b) formed by filling of fractures associated with collapse features.

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BRICK RAW MATERIAL RESOURCES OF SOUTH CAROLINA

By

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INTRODUCTION

At the beginning of the Colonial period in South Carolina and for many years thereafter bricks were made for construction purposes in hundreds of small plantation, community, or behind-the-barn operations. Any clayey material readily at hand and plastic enough to be formed and to hold its shape during firing was used. Color and texture were incidental and accidental. Even so some attractive brick were made at this time.

With the change to large volume, highly competitive brick production many of the local raw material sources became unusable because of the limited volume and variable quality of the material. Large, homogeneous deposits of suitable raw materials were sought, found, and developed - shale, for instance. Now with the ever increasing need for a variety of colors and textures, large homogeneous deposits of shale or clay are not enough. Additional clay and mineral types that can be added to the base raw material are needed to provide workability and the colors and textures that can command premium prices and fulfill the needs of the consumer.

Sources of the necessary clay and mineral additives for the brick manufacturer are many and varied, but because of freight costs today's brick producer should take advantage of the raw materials that are within easiest reach.

The purpose of this paper is to point out the sources of brick raw materials, including clay and mineral additives, in South Carolina.

GEOLOGIC SETTING OF SOUTH CAROLINA

Geologically South Carolina can be subdivided into three provinces. From southeast to northwest these are the Coastal Plain, Piedmont, and Blue Ridge (Figure 1). The rocks and general geology of the Blue Ridge and Piedmont provinces are essentially the same and can be combined for discussion of ceramic raw materials. There are then two broad geologic divisions — (1) the crystalline rock terrane of the Blue Ridge and Piedmont and (2) the sedimentary rock terrane of the Coastal Plain. The dividing line between the two terranes is known as the "Fall Line" (Figure 1).

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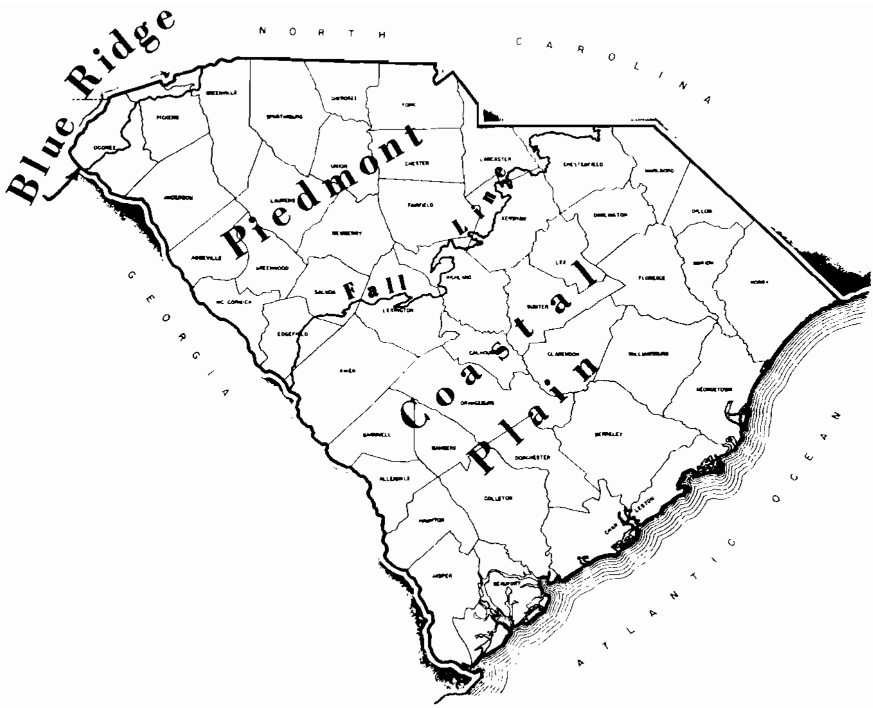

Figure 1. Major physiographic divisions of South Carolina.

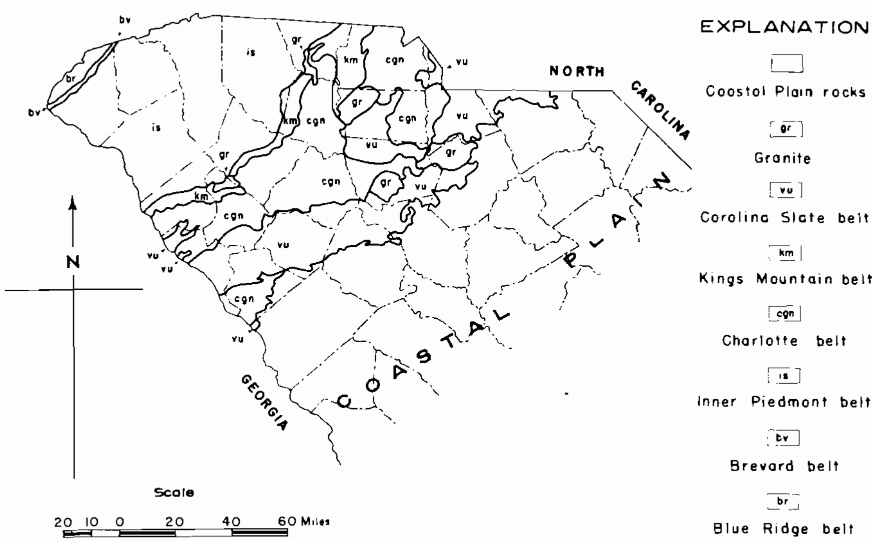

Figure 2. Major geologic belts of the Piedmont.

Blue Ridge and Piedmont

The Blue Ridge and Piedmont area is made up of crystalline igneous and metamorphic rocks. In general there are broad bands, many miles wide, of rather coarsely crystalline granites, schists, and gneisses alternating with broad bands of finer grained rocks called slate, shale, phyllite, argillite, or sericite schist.

Coarse Grained Rocks

The granites, schists, and gneisses have in many places weathered to clayey soils and saprolite (rock weathered in place to clayey, porous residual material that still shows the texture and structure of the original rock). The soil and saprolite vary in sand content depending on the amount and grain size of quartz in the original rock. Because of thin quartzose character many of these weathered coarse grained crystalline rocks are not suitable for ceramic use without considerable beneficiation. Some may be used effectively as additives, a point to be considered below.

Fine Grained Rocks

The fine grained rocks of the Blue Ridge and Piedmont are confined essentially to three broad bands known as the Brevard Belt, Kings Mountain Belt,and Carolina Slate Belt (Figure 2). The principal brick raw materials in these belts are shale, sericitic kaolin, sericite schist, and manganese schist.

Shale. - The Carolina Slate Belt (Overstreet and Bell, 1965, p. 18-29) has the largest reserves of shale, but it also occurs in tremendous tonnages in the Brevard and Kings Mountain belts. Shale is usually an excellent basic ingredient for brick manufacture. It is easily minable and has reasonably low drying and firing shrinkage. It generally provides a rather limited range of reddish colors and is sometimes troublesomely lacking in plasticity.

Sericitic Kaolin. - Small to medium size deposits of sericitic kaolin can be found in the Fall Line zone at or near the Carolina Slate Belt-Coastal Plain contact. It is less refractory than pure kaolin and fires to white or off-white color. It can be used as an extender of kaolin in buff brick bodies where kaolin is in short supply or where a lower firing temperature is needed. It is reported that the clay from some of these deposits may cause brick to effloresce a green color. Each deposit should be checked for this characteristic.

Sericite Schist. - Some sericite schist is similar to the sericitic kaolin and may be its unweathered parent material. Sericite schist is composed of fine grained quartz and fine muscovite mica (called sericite).

It is white in color and generally light firing at low temperatures. It has low plasticity and consequently low shrinkage. It may be used as an additive or basic ingredient in buff brick or tile.

Manganese Schist. - Manganese schist deposits are known in the Kings Mountain belt and may be present in the Brevard Belt as well. This additive gives purplish brown to black colors.

Plastic Clays

Both the coarse and fine grained mafic (basic) rocks of the Piedmont commonly weather to plastic reddish to brown clays. These rocks include gabbro and amphibolite of the Charlotte Belt and basic volcanic rocks of the Kings Mountain and Carolina Slate Belts. The clay has considerable potential as an additive to increase plasticity of shales.

Piedmont River Clays

Silty to sandy plastic kaolinitic clays are present in many creek and river floodplain deposits, especially in the Piedmont although some deposits may occur in the Blue Ridge. The floodplain clays are commonly variable in sand content and are seldom over a few feet in thickness, but considerable tonnage may in some instances be obtained over a large area within the floodplains of the larger rivers. The clay is frequently suitable as a basic raw material for brick manufacture or as an additive to give plasticity to shale.

Other Additives

The Blue Ridge and Piedmont offers a variety of materials useful in some brick products. These include (1) granite screenings, available at large granite quarries, suitable in some instances as a flux or a filler to reduce shrinkage; (2) ground feldspar useful as a flux; (3) dolomite, another useful flux, and (4) pyroxene, amphibole, and epidote, useful as additives for reducing shrinkage.

COASTAL PLAIN

The rocks of the Coastal Plain are of sedimentary origin, and they have not been disturbed or recrystallized as have those of the Blue Ridge and Piedmont. The Coastal Plain rocks may be grouped into about 12 natural units or formations (Heron, Robinson, and Johnson, 1965, p. 12). Each of these formations represents material deposited during a certain period of time and under certain general environmental conditions. The oldest exposed formations are of Cretaceous age (about 100 million years old), and these are in general overlain southeastward by successively younger formations (Figure 3). The beds dip gently toward the sea but

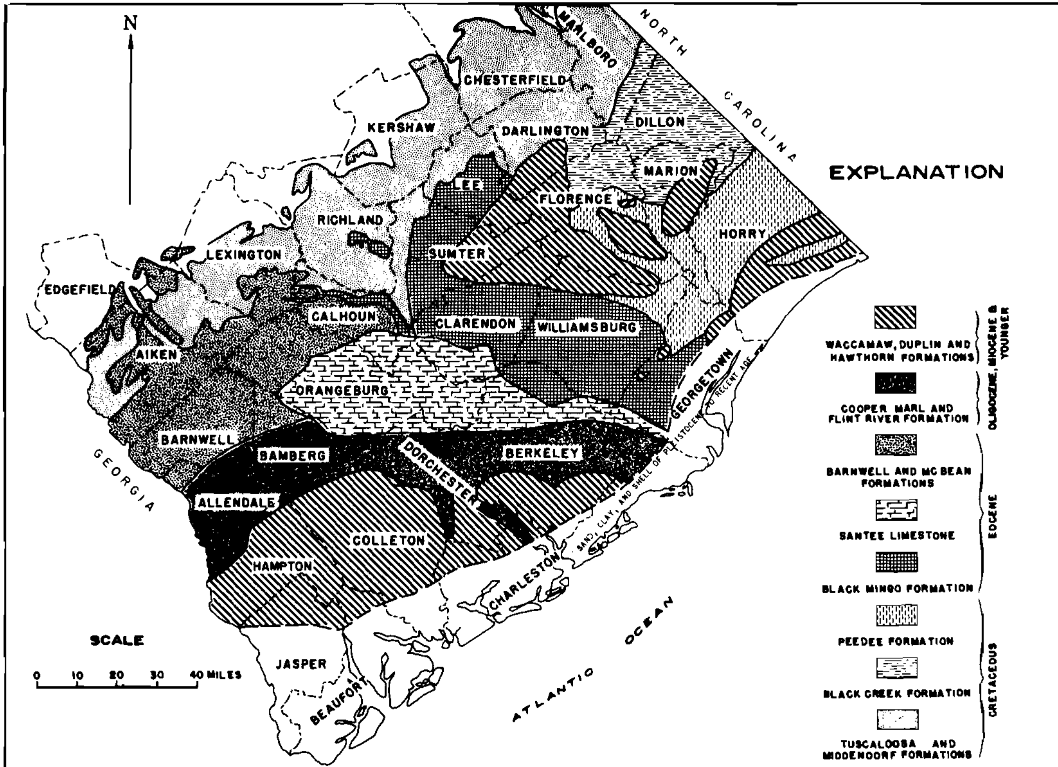

Figure 3. Generalized geologic map of the Coastal Plain of South Carolina

within any limited area they are essentially horizontal. The oldest Cretaceous beds, which crop out near the "Fall Line", are ancient river deposits; but most of the other Coastal Plain deposits were laid down in shallow seas. Modern river floodplain deposits (Heron, Robinson, and Johnson, 1965, p. 30) cut across and overlie older Coastal Plain formations.

Mineralogically, and to a large extent ceramically, the brick raw materials of the Coastal Plain may be grouped into three broad categories: (1) kaolinitic clays, (2) montmorillonitic clays, and (3) opal claystone. Each type has distinctive properties, but there is commonly a certain amount of mixing of the types with consequent integradation of ceramic properties. In general the kaolinitic clays occur in ancient stream deposits and represent river floodplains. Montmorillonitic clays are characteristic of marine deposits. Opal claystone is essentially confined to the Black Mingo Formation of Eocene age.

Kaolinitic Clays

The South Carolina Coastal Plain kaolinitic clays are high in the clay mineral kaolinite. Montmorillonite and illite are usually present in small amounts. The working and firing properties are characteristic of kaolinite – that is, low water of plasticity, low drying and firing shrinkages, low to medium dry strength, and medium to high maturing temperatures. These properties are significantly altered with increasing quantities of montmorillonite.

The occurrence of sedimentary kaolin of high purity is limited to the non-marine Cretaceous sediments of the Middendorf (Tuscaloosa) Formation (Figure 3). High kaolinitic clays are also found in the floodplain deposits of rivers that flow out of the Piedmont and across the Coastal Plain (Peedee, Wateree, etc.). These clays usually have montmorillonite as an impurity and consequently are plastic and red firing. The main disadvantage of these clays is the possible lack of homogeneity, especially in the sand content.

Montmorillonitic Clays

Montmorillonite is a super clay material and as such is a useful additive to modify the characteristics of shales, kaolin, etc. Most montmorillonitic clays contain more than 25 percent montmorillonite but as little as 5 percent by weight of montmorillonite may significantly alter the physical and firing characteristics of a clay material.

The characteristics of a high montmorillonitic clay are generally undesirable for they have high water of plasticity, high drying and firing shrinkages, high dry strength, and low maturing temperatures. They are commonly hydroscopic and can pick up large amounts of water from a humid atmosphere. On firing montmorillonitic clays often vesiculate.

Although pure montmorillonitic clays are generally useless as a base raw material, small quantities of such clays may be of considerable value as an additive to improve plasticity and lower maturing temperatures.

Occurrences. - Coastal Plain montmorillonitic clays are widespread. The formations mentioned below have the most notable deposits.

The McBean Formation in Orangeburg and Calhoun Counties contains a clay bed of 5 to 15 foot thickness that is found over a considerable area (Heron, Robinson, and Johnson, 1965, p. 24, 41-44). The clay bed is locally very pure.

The Black Creek Formation in Florence and Darlington Counties contains layers and lenses of clay materials as thick as 15 feet (Heron, Robinson, and Johnson, p. 15, 39-40).

The Hawthorn Formation in Beaufort and Jasper Counties contains a widespread highly montmorillonitic clay called the Coosawhatchie clay. It has a maximum thickness of up to 25 feet and is located near the surface. Attapulgite clays are also found in the Hawthorn Formation.

Pleistocene marine clays are found in the lower Coastal Plain. These clays have been deposited in ancient lagoons behind barrier bars (Heron, Robinson, and Johnson, p. 27-28). The deposits are up to 20 feet or more thick and are of wide extent. The clays are commonly kaolinitic montmorillonite. The near surface parts of the clay deposits are often more kaolinitic than the same deposits at depth because of surface alteration by weathering of montmorillonite clay to kaolinite. Caution must be exercised in sampling and mining these clay deposits because of this change downward.

Opal Claystone

The pure varities of this unusual ceramic material have a low bulk density and high porosity. Bulk density ranges from 0. 7 grams/cc to 1. 2 grams/cc and porosity ranges from 50 to 70 percent. The pure material has low plasticity and poor extrusion characteristics, but some varieties contain abundant montmorillonite as an impurity with a resulting improvement in plasticity and extrusion characteristics. The purer varieties are fairly refractory and maintain thin low bulk density and high porosity on firing to temperatures as high as 2400°F.

Opal claystones vary from a light buff color on weathered outcrops to a medium to dark gray or black when fresh. The ligher colored material usually has the highest porosity and lowest bulk density. The darker colored claystones generally have more admixed montmorillonitic clay and consequently have a reduced apparent porosity, a higher bulk density, a reddish color upon firing, and lower melting temperatures.

The opal claystones commonly have very low strength in fired samples. Possible use in brick manufacture would be as sand coatings or as inclusions in the body of the brick to reduce weight.

The purest deposits of opal claystone occur in the Black Mingo Formation (Figure 3) but it does occur as a minor impurity in some of the montmorillonitic clays of the McBean and Congaree Formations of Calhoun and Orangeburg Counties (Heron, Robinson, and Johnson, p. 19-21, 33).

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