MACROSEISMIC EFFECTS OF THE 1886 CHARLESTON EARTHQUAKE

CAROLINA GEOLOGICAL SOCIETY FIELD TRIP

Charleston, South Carolina

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Field Guides: Pradeep Talwani and Michael Katuna

Macroscopic Effects of the 1886 Charleston Earthquake

Pradeep Talwani
Department of Geological Sciences
University of South Carolina
Columbia, South Carolina 29208

INTRODUCTION

The most destructive earthquake ever recorded in eastern U.S. occurred near Summerville, about 35 km northwest of Charleston, South Carolina on August 31, 1886. The earthquake was felt over 5 million square kilometers, caused $5M damage and estimates of loss of life range between 60 and 110. There were several macroseismic effects in the meizoseismal area which were carefully described by contemporary observers and are still visible today. Our understanding of the seismogenic structures associated with this earthquake has improved over the years. In this field trip we will visit three locations where the effects of the 1886 earthquake are visible today and examine them in light of our understanding of the seismotectonic framework.

Another phenomenon associated with the 1886 event was seismically induced liquefaction, which is accompanied by forceful ejection of sand and water and the formation of sandblows and craters. Liquefaction is caused by an increase in pore-water pressure during passage of seismically generated shear waves. If the pore-water pressure increases to a point equal to that of the confining pressure, the effective stress drops to zero and the soil will enter a liquefied state. During the 1886 earthquake, sandblows were widespread in the meizoseismal area. A study of sandblows is now used as a method of finding evidence of prehistoric earthquakes. In this field trip, we will visit a drainage ditch near Hollywood popularly referred to as the "Hollywood ditch", where several sandblows were discovered in the mid 1980s.

SEISMOTECTONIC BACKGROUND

Various accounts (see e.g. Dutton, 1889; Sloan as quoted in Charleston year book of 1886) argue for a sequence of two or three large shocks on the night of August 31, 1886. The seismicity in the area has been monitored instrumentally since 1973 and is mainly concentrated in the Middleton Place Summerville Seismic Zone (MPSSZ) with a small cluster defining the Adams Run seismic zone (Figure 1). These seismic zones were originally identified by Tarr et al. (1981). In the earliest attempt to explain that observation, Talwani (1982) suggested that the current seismicity (and by implication the 1886 earthquake sequence) was associated with two intersecting faults – the NNE trending Woodstock fault (WF) extending NNE from Adams Run and the NW trending Ashley River fault (ARF). The faults intersected south of Summerville. He further suggested that the steeply dipping (to W) Woodstock fault was primarily associated with right-lateral slip and the ARF was associated with reverse faulting (SW side up) in response to a plate tectonic stress field with the maximum horizontal stress (S_{Hmax}) oriented N60°E. Subsequent analysis of the seismicity by Garner (1998) suggested that the ARF cuts and offsets the Woodstock fault in a left-lateral sense by ~5-7 km. Very recently, Dura-Gomez (2004) has analyzed the seismicity data (to 2003) and compared it with available geological, geophysical, and geodetic data to arrive at a revised seismotectonic framework. According to this revised framework (Figure 2) the

Woodstock fault consists of two segments, the N33°E trending and NW dipping Woodstock fault South (WF(S)) which is intersected by N30°W trending (and SW dipping) Sawmill Branch fault (SBF) which offsets WF(S) by ~8 km to the NW where it continues as Woodstock fault North (WF(N)). The strike of WF(N) varies from ~N30°E to N15°E with an average of N23°E. Both legs of Woodstock fault are associated with oblique right-lateral slip motion and local uplifted regions, whereas SBF is primarily associated with reverse faulting with the SW side up and left-lateral slip and is currently the most active. Based on hypocentral distribution, all fault zones are about 4-5 km wide. The uplifted zones along WF were recognized as zone of river anomalies (Marple and Talwani, 1993; 2000). Pronounced uplift was also recognized south of Summerville by Rhea (1989). So according to our current thinking the 1886 earthquakes were associated with uplift along the N30°W trending SBF, and right-lateral oblique slip on the Woodstock fault, and both uplift and rotation in the intersecting zones.

FIELD TRIP

Start – From the Town and Country Inn, Charleston

Turn right at the parking lot
Go 0.2 miles and turn onto I-526 East (N. Charleston)
Go 1.3 miles and exit at Ashley River Road –North
Take Glen McConnell Blvd for 0.9 miles – turn right into Magwood Road
Go 0.8 miles and turn left onto Highway 61
Go ~5.1 miles to entrance of Magnolia Gardens

STOP 1: MAGNOLIA GARDENS

Turn right into Magnolia Gardens. Follow signs to parking lot (Figure 3). On walking paths follow numbered signs to location #11.

THE DRAYTON FAMILY TOMB

In "The Story of Historic Magnolia Plantation and its Gardens. Their First 300 Years" by Mr. John Drayton Hastie, Charleston, South Carolina, there is the following description of the Drayton Family Tomb on the bank of the Ashley River.

"The Drayton Family Tomb was constructed sometime prior to 1700 by Thomas Drayton, Jr., its first occupant. It became the resting place of subsequent owners and of their families until 1891. Since then, it has been utilized only by Drayton F. Hastie, uncle of the grandfather of the present owner, in 1916.

The marble plaque on the face of the tomb was carved by Jardella, the Nation's first sculptor of note. The features of the cherubs were vandalized by the bayonets and rifle balls of occupying U.S. Army troops, who also burned the plantation house in 1865. The large crack was incurred in the earthquake of 1886, which leveled Charleston."

You can see a large crack on the front side in the marble carving of the cherubs and through the lower platform on the back side. (The marble plaque on the back side was put in ~60 years ago according to Mr. Hastie, owner, ~1/2000). The direction of the crack, NW is along the strike of the Ashley River fault inferred from seismicity data (Talwani, 1982; Madabhushi and Talwani, 1993; Garner, 1998). We infer that the crack was caused by movement on the SBF-Ashley River fault in 1886.

WILDLIFE OBSERVATION TOWER

Follow the trail, west, along the Ashley River, through the Camelia Trail to the Wildlife Observation Tower. Notice the wide expanse of the Ashley River (~1 km wide).

Return to parking lot.

Exit Magnolia Gardens, turn right on County Road 61. Go ~8.8 miles and turn right on County Road 165, cross County Road 642 (1.6 miles) and continue 3 miles through town to intersection with highway 17A. Cross 17A and you are now on East Carolina Street. Go 0.6 miles and turn left on Waring Street and proceed ~100 m to the parking lot pf St. Paul's Episcopal Church.

STOP 2: ST. PAUL'S EPISCOPAL CHURCH

The Episcopal Church in the southwestern part of Summerville bears evidence of the Charleston earthquake. The damage there was described by W. J. McGee of the U.S. Geological Survey. The church is a wooden structure ~30ft × 50ft resting on 36 piers of brick, each 2.5ft square and 4ft high. Due to the earthquake, the N80°E striking side of the church (nearest parking lot) moved 2.5" at its NE corner and 1.75" in the middle, and 1" at its southeast corner. This implied a clockwise rotation of the church (Figure 4). A similar clockwise rotation was seen in a tombstone. The tombstone made of four blocks showed evidence of clockwise rotation (see William McGee's first hand account). In this account McGee made a mistake in transcribing from his field notes. The front of the church is oriented ~N10°W – S10°E and not N70°E. The tombstone was restored. However, in the cemetery one can find other tombstones that bear evidence of the 1886 earthquake.

The Episcopal Church lies approximately at the southern end of the Woodstock fault (North) and near its intersection with the Sawmill Branch fault (Figure 4). This part of town bore evidence to large vertical displacements (see McGee's account). Evidence of vertical movement can be seen in the house, appropriately named, "Out of Plumb" at 126 Lynwood Lane, about 0.2 miles south of the church. (Due to a change of ownership, we will be unable to visit "Out of Plumb").

The vertical and rotational movements observed in the intersection zone are interpreted as being due to movements on both faults.

From the church take a right on East Carolina Street, go 0.6 miles to intersection with highway 17A to County Road 165, 3 miles to intersection with County Road 642. Turn left on County Road 642, go 2 miles and turn right into Old Dorchester State Park. Proceed to the parking lot.

STOP 3: OLD DORCHESTER STATE PARK

The Old Dorchester State Park contains the abandoned town of Dorchester, a damaged church and an ancient fort on the banks of the Ashley River. The fort was built on the northern bank of the river using tabby (roasted oyster shells as mortar) in 1775. The town of Dorchester was torn down brick by brick and moved to Summerville. An old church was badly damaged by the earthquake but is still standing. On the field trip, we will visit the remnants of the church and the tabby fort. (Please see appended descriptions of Fort Dorchester and the old church).

We will eat lunch at Old Dorchester State Park.

CRACKS IN THE OLD FORT

On the long southern wall of the fort, there is a remarkable crack ~47 feet (14.3 m) from the east end of the wall. This crack has cut the 2.5 feet thick, 7 feet high tabby wall and moved it in a left-lateral sense by ~10 cm (point A in Figure 5). A similar left-lateral displacement is seen in the northern wall, about 9.5 feet (2.9 m) from the northwest corner of the fort. (The southwest wall shows evidence of slumping into the river and was restored in the 1980s). The two cracks in the northern and southern walls of the fort exhibit left-lateral displacement of ~10 cm along ~N20°W (Figure 5). Other cracks in the eastern and western walls do not show any lateral displacement or a systematic pattern of deformation. [The description in the Appendix is taken from Dutton's account of the Charleston earthquake (pages 297-298). In the second paragraph, Dutton describes the damage to the fort *"especially at the northeast corner"*. This description is based on Sloan's account. However perusal of Sloan's account [see Peters and Hermann (editors) p.59] shows that Dutton had misquoted Sloan. According to Sloan's account *"Old Fort walls of shell concrete 8ft high with thickness battered from 3ft at base to 2 ft at top cracked through E wall at SE corner also badly cracked in two places at **N.W.** corner (emphasis added)"*. From these data Sloan inferred a N20°W trend – similar to our interpretation (Figure 5). The displacement is interpreted as being caused by oblique offset of the Sawmill Branch fault.

Between the fort and the river, Dutton (1889) reported that there were *"several wide cracks in the ground parallel to the river"*. These cracks were likely associated with slumping of the ground.

THE WIDTH OF THE ASHLEY RIVER

The fort was built on the northern bank of the Ashley River and was the terminus for river transport from Charleston. Note how narrow the Ashley River (<50m across) is as compared to its wide expanse near Magnolia Gardens. Uplift associated with the Sawmill Branch fault caused the Ashley River to incise and follow a narrow channel.

FALLING PIECES FROM THE CHURCH

Based on Earle Sloan's observations, Dutton (1889) noted that..

"Of the church, all that remained at the time of the earthquake was the tower, which was 18 feet square at the base and rose to a height of nearly 40 feet. The walls of this tower on the northwest and southeast sides were 3 feet 10 inches thick, and on the other two sides about two feet thick. From its summit large blocks of brick and mortar-as much as 15 or 20 cubic feet in each block-were dislodged and hurled in four directions. One large mass struck the ground 35 feet from the base of the tower on the northeast side, and in its descent striped branches and bark from a tree with which it came in contact. Another mass of nearly equal volume was hurled in the opposite direction from the summit of the tower and to an equal distance. Large masses were also thrown in directions at right angles to the above, but not to such great distances. It was my privilege to view those relics under the guidance of Mr. Sloan, and after studying them carefully I could see no escape from his conclusion that the greater fragments had been actually projected to a distance of 35 feet from the base of the tower. That the blocks did not strike the ground nearer to the base and roll farther away was clearly established by most careful investigation, and the lacerated bark and branches of the tree immediately above the spot where the largest block lay was to my mind conclusive".

This tree was located N60°E of the tower, i.e., the largest blocks were flung in a N60°E-S60°W direction. Interestingly, N60°E is also the direction of maximum horizontal compression in the Charleston area (Madabhushi and Talwani, 1993; Talwani et. al., 1997).

The flinging of the blocks is, therefore, interpreted as the coseismic response to the release of stored stress in the meizoseismal area.

Return to the parking lot, exit the Old Dorchester State Park, turn left on County Road 642. Go 2 miles and turn left on County Route 165, cross County Route 61, and State Highway 17 (at Ravenel). Go ~21.5 miles to 0.2 miles north of intersection with County Route 62. Turn left on Ball Park Road. Stop. Walk back north along Route 165 about 100 feet and turn right on access road, north of Hollywood ditch.

STOP 4: PALEOLIQUEFACTION SITES

During the summer of 1983, a sandblow associated with the 1886 earthquake was excavated and analyzed (Cox and Talwani, 1983). After that discovery, Steve Obermeier and his colleagues from the U.S. Geological Survey discovered sandblows associated with prehistoric earthquakes in the Hollywood ditch. Further excavations in the Hollywood ditch by scientists from USGS and the University of South Carolina led to the discovery of eight paleoliquefaction features and 20 radiocarbon ages (see Talwani and Schaeffer, 2001 for a review). Analyses of those data provided evidence in the Hollywood ditch for at least five prehistoric earthquakes dating from about 500 to 6000 years b.p. The excavations made in the 1980s have been overgrown. However, we will see some recently excavated features. A paper describing the use of paleoliquefaction features for determining recurrence times of large earthquakes and an extract of a paper describing paleoliquefaction studies in the Coastal Plain of South Carolina are appended.

From Ball Park Road (Ditch) take Route 162, go 7 miles to the intersection of Highway 17. Take a right onto Highway 17 North for 7.7 miles to the entrance of the Town and Country Conference Center.

ACKNOWLEDGEMENTS

I am grateful to the late Mr. Hastie former owner and Mr. Taylor Nelson, current owner of Magnolia Plantations for their interest and help. I thank Abhijit Gangopadhyay for help in compiling the field guide.

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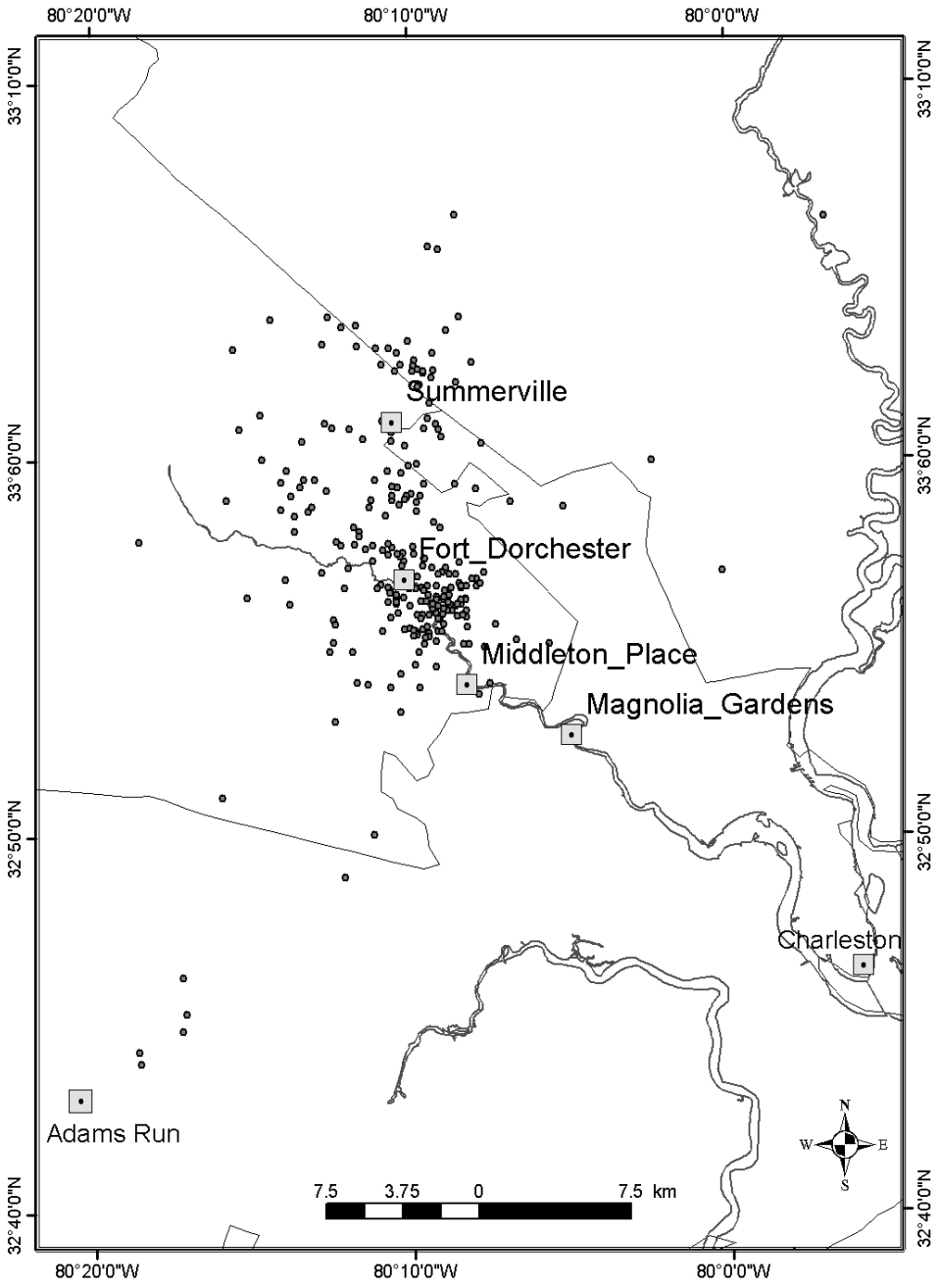


Figure 1: Instrumental seismicity (1974-2003) in the Middleton Place Summerville Seismic Zone near Charleston, South Carolina

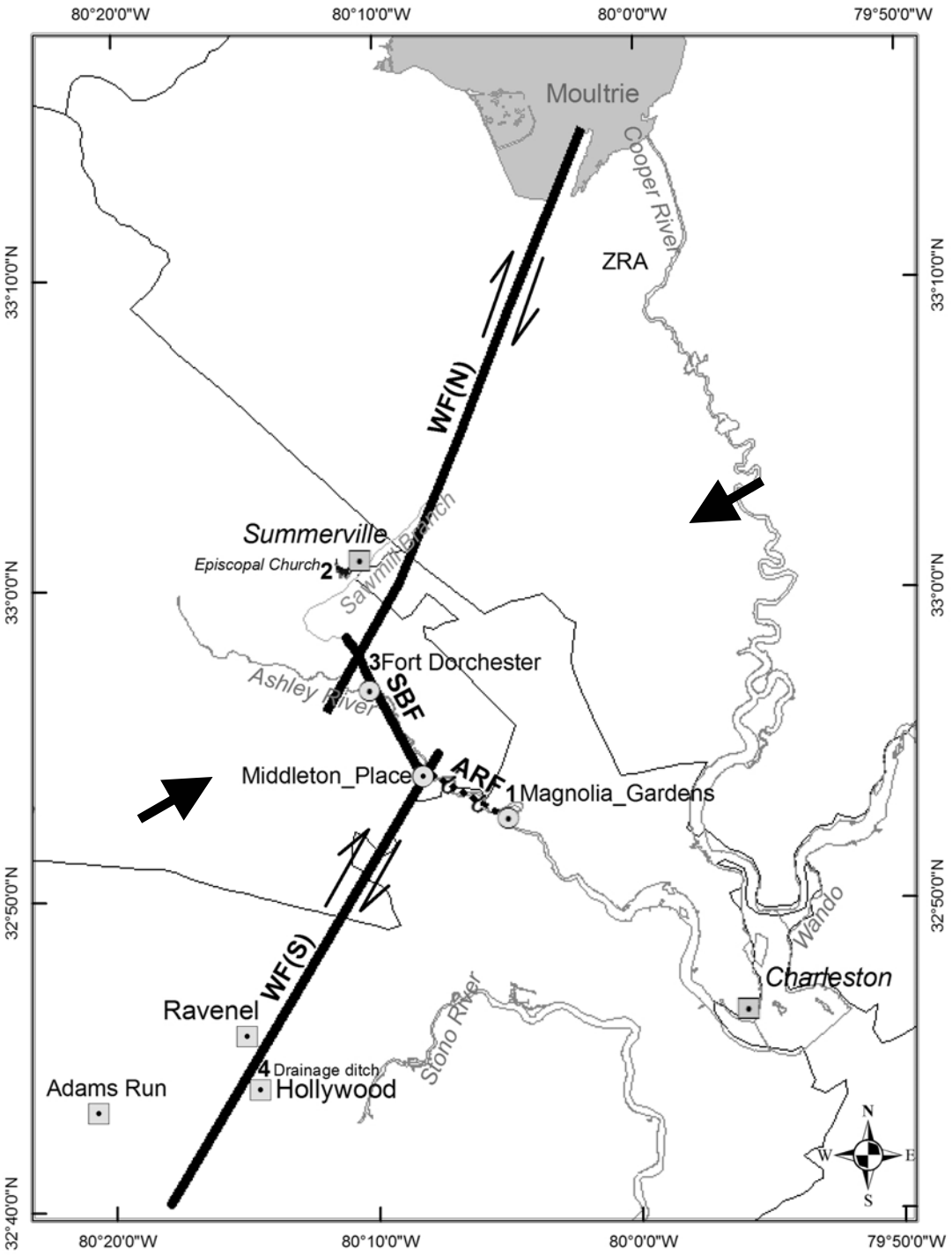


Figure 2: Schematic figure showing the revised seismotectonic framework. The NE trending Woodstock fault (South) (WF(S)) is offset by the N30°W trending Sawmill Branch Fault (SBF) and continues as Woodstock fault (North) (WF(N)). Most of the current seismicity lies in a zone where the two fault zones intersect. The bold arrows indicate the direction of maximum horizontal stress in the region. The numbers (1-4) show the locations of stops on the field trip.

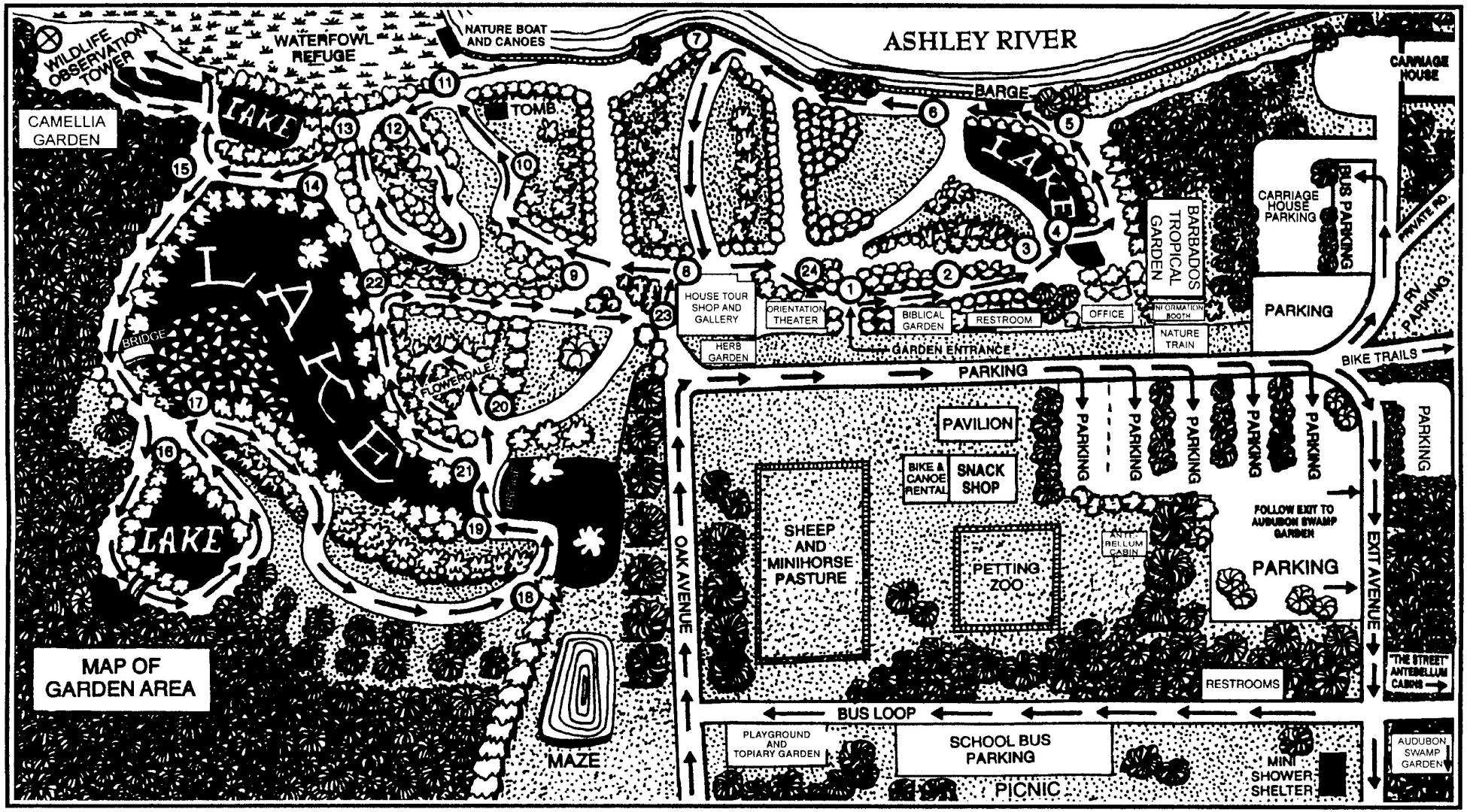
(SEE REVERSE FOR SUGGESTIONS)

Figure 3

Magnolia Plantation and Its Gardens

Listed in the National Register of Historic Places

Note: FOLLOW NUMBERED SIGNS!



(SEE REVERSE FOR SUGGESTIONS)

Note: this map does not include the lovely **AUDUBON SWAMP GARDEN.** To visit this nationally-acclaimed garden, purchase your ticket at the **INFORMATION BOOTH** or **OFFICE.** The entrance is on the left, just before you reach Hwy. 61 as you exit the Plantation.

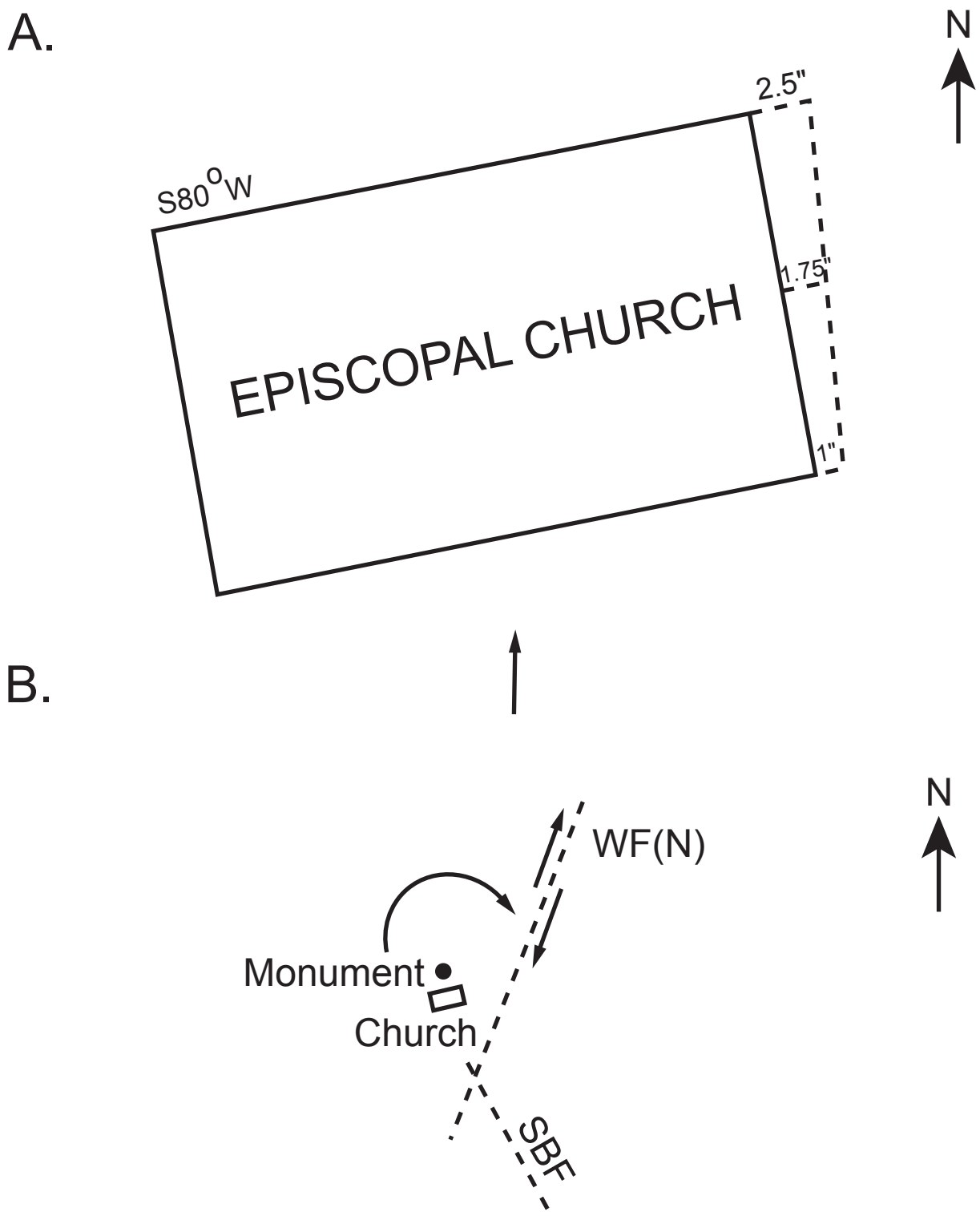


Figure 4: Schematic of the Episcopal Church in southwest Summerville and its relationship to WF(N) and SBF. The offsets of the church are in inches and are not plotted to scale.

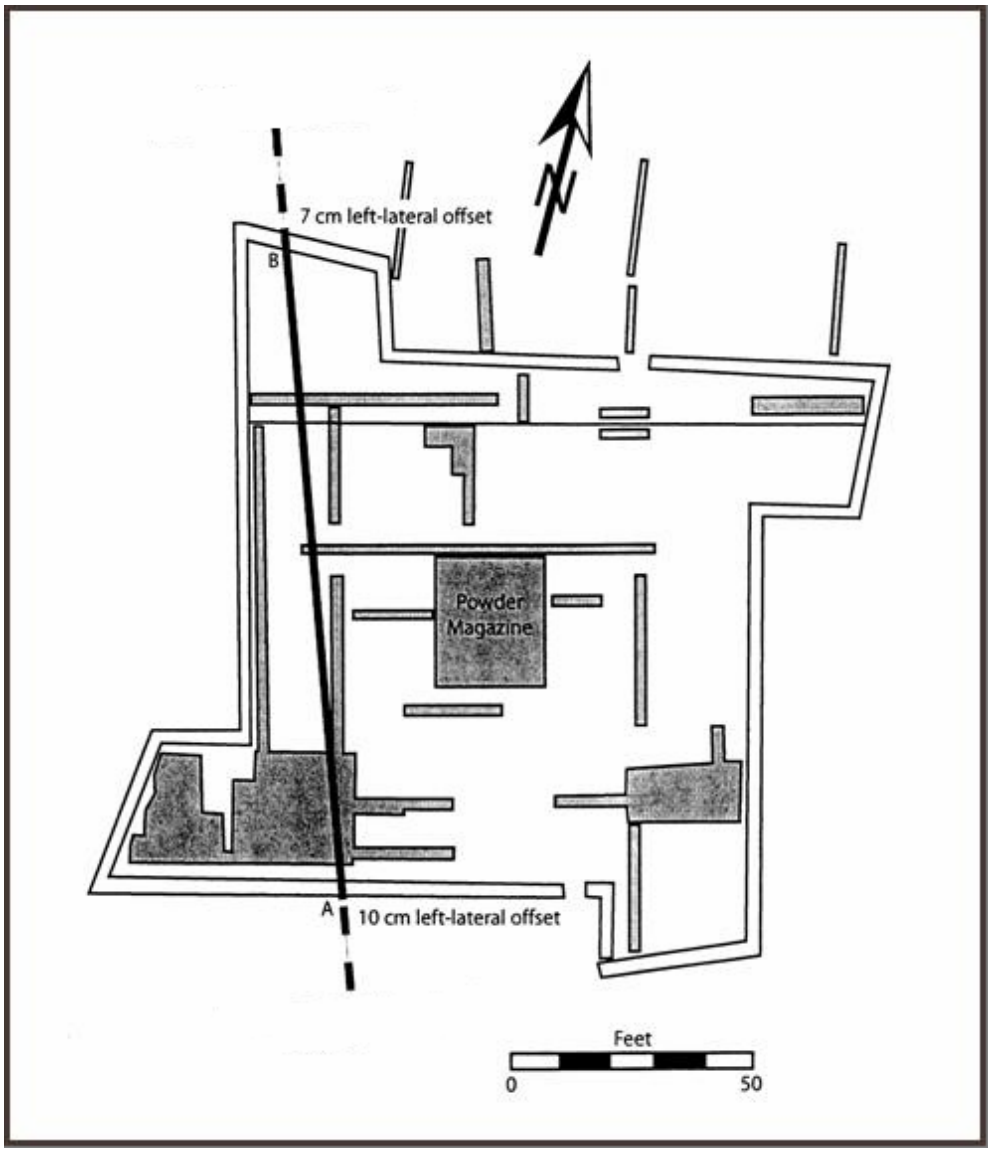


Figure 5: Plan of Fort Dorchester showing locations where the tabby walls have been offset – defining the fault trend

APPENDICES

Stop 2

was immediately observed on reaching Summerville that direction of destructive motion was vertical rather than zontal and that the chimneys seldom appeared to have thrown but to have been simply crushed and then to have led over. Examples will be noted farther on. The Episcopal ch in the south-western part of town a wooden structure 50 feet resting on 36 piers of brick each 2 1-2 feet square 4 feet high, fronting N 70° E, has been displaced ward 2 1-2 inches at the west end, 1 3-4 inches in the dle, and 1 inch at the east end. This northward displace- of the church has not carried with it any of the 9 pillars the south wall; but one or two of the pillars under the wall and several of those beneath the church have aken of its movement. Several of the pillars, however, pit crushing at their summits and a few have oblique res extending throughout them — these fissures generally ding from the south obliquely downward to the north. The ing is more pronounced in the four pillars beneath the corner posts of the church and is nil in many of the pillars th the floor and under the front of the light wooden

monument 20 feet north of the church is represented in (Figure 26). *The cross, estimated to weigh 100 lbs, has n below which was fitted and cemented into a shallow e in its base b, weighing perhaps 25 lbs. The effect of ock was to break the cross from its socket and throw it to the westward which is shown in fig. 7* (Figure 26). *se b is torsionally displaced with the sun 2 1-2 inches. 0 lb block c was twisted in the same direction 3-4 of an d moved slightly northward, and the 150 lb block d was in the same direction 1-2 inch and also shifted north- ghtly while the 300 lb base is undisturbed.*

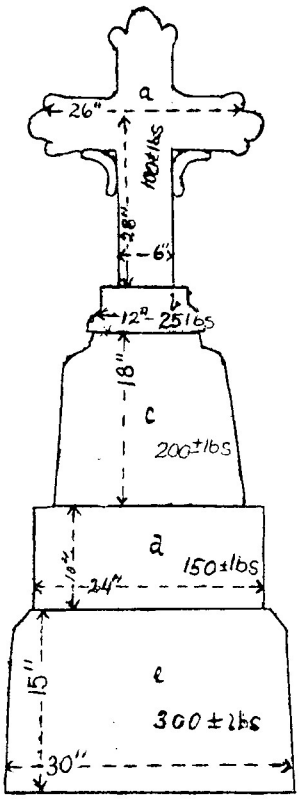


Fig. 6.

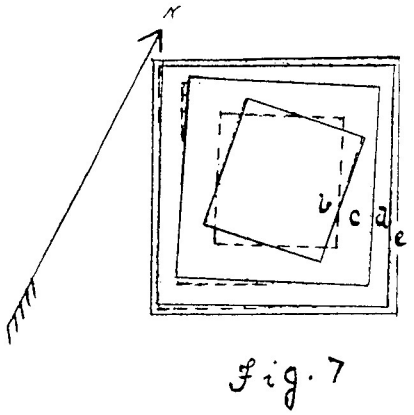


Fig. 7

Figure 26. "Figures 6 and 7." Monument at St Paul's Episcopal Church, Summerville. Sketches by W J McGee.

FROM: W.J. M°Gee's Account
Peters, K.E., Herrmann, R.B., editors, First-Hand Observations of the Charleston Earthquake of August 31, 1886, and other Earthquake Materials, Bulletin 41 Of South Carolina Geological Survey, 1986

Stop 3

At a point about four and a half miles southwest of the epicentrum we come upon one of the most interesting and instructive monuments of the earthquake to be found in the whole epicentral tract. The locality is the site of an old town named Dorchester, long since abandoned and overgrown with forest. The place has interesting historic associations with colonial and revolutionary times, and has been made the scene of one of Gilmore Simms's most pleasing classic stories. In a thick wood, a few hundred yards from the Ashley River, stands the ruin of an old brick church. Around it are the fallen and moldering gravestones of the forgotten dead overgrown with brush and jungle. Of the church, all that remained at the time of the earthquake was the tower, which was 18 feet square at the base and rose to a height of nearly 40 feet. The walls of this tower on the northwest and southeast sides were 3 feet 10 inches thick , and on the other two sides about two feet thick. From its summit large blocks of brick and mortar-as much as 15 or 20 cubic feet in each block-were dislodged and hurled in four directions. One large mass struck the ground 35 feet from the base of the tower on the northeast side, and in its descent striped branches and bark from a tree with which it came in contact. Another mass of nearly equal volume was hurled in the opposite direction from the summit of the tower and to an equal distance. Large masses were also thrown in directions at right angles to the above, but not to such great distances. It was my privilege to view those relics under the guidance of Mr. Sloan, and after studying them carefully I could see no escape from his conclusion that the greater fragments had been actually projected to a distance of 35 feet from the base of the tower. That the blocks did not strike the ground nearer to the base and roll farther away was clearly established by most careful investigation, and the lacerated bark and branches of the tree immediately above the spot where the largest block lay was to my mind conclusive. (Pl. XXII.)

A little beyond this ruin is the Ashley River, where there still stands an old fort, built of a peculiar concrete, consisting of oyster shells embedded in a lime-mortar obtained by burning and calcining oyster shells-the same shell-lime which Dr. Manigault praises so highly. It deserves his praise, for the old fort-wall, built more than a hundred years ago, is as fresh and hard as newly cut granite. But the earthquake broke it in many places and severely cracked it, especially at the northeast corner. Hard by the fort are several wide cracks in the ground parallel to the river.

THE CHARLESTON EARTHQUAKE
of
AUGUST 31, 1886
BY
CAPT. CLARENCE EDWARD DUTTON
Based on a description by Earle Sloan.

The Old Parish Church

The most conspicuous object remaining on the site of the old village of Dorchester is the ruined tower of the old church. This is all that is left of the Parish Church of St. George's, Dorchester. It is not as is sometimes supposed the Congregational Church of the old immigrants from Dorchester, Massachusetts, but the church constructed when the Church of England was the established church of the Province. The Statute providing for its construction was enacted in 1719. This Statute appropriated £333.6s 8d (Carolina paper currency) to assist in defraying the cost of construction.

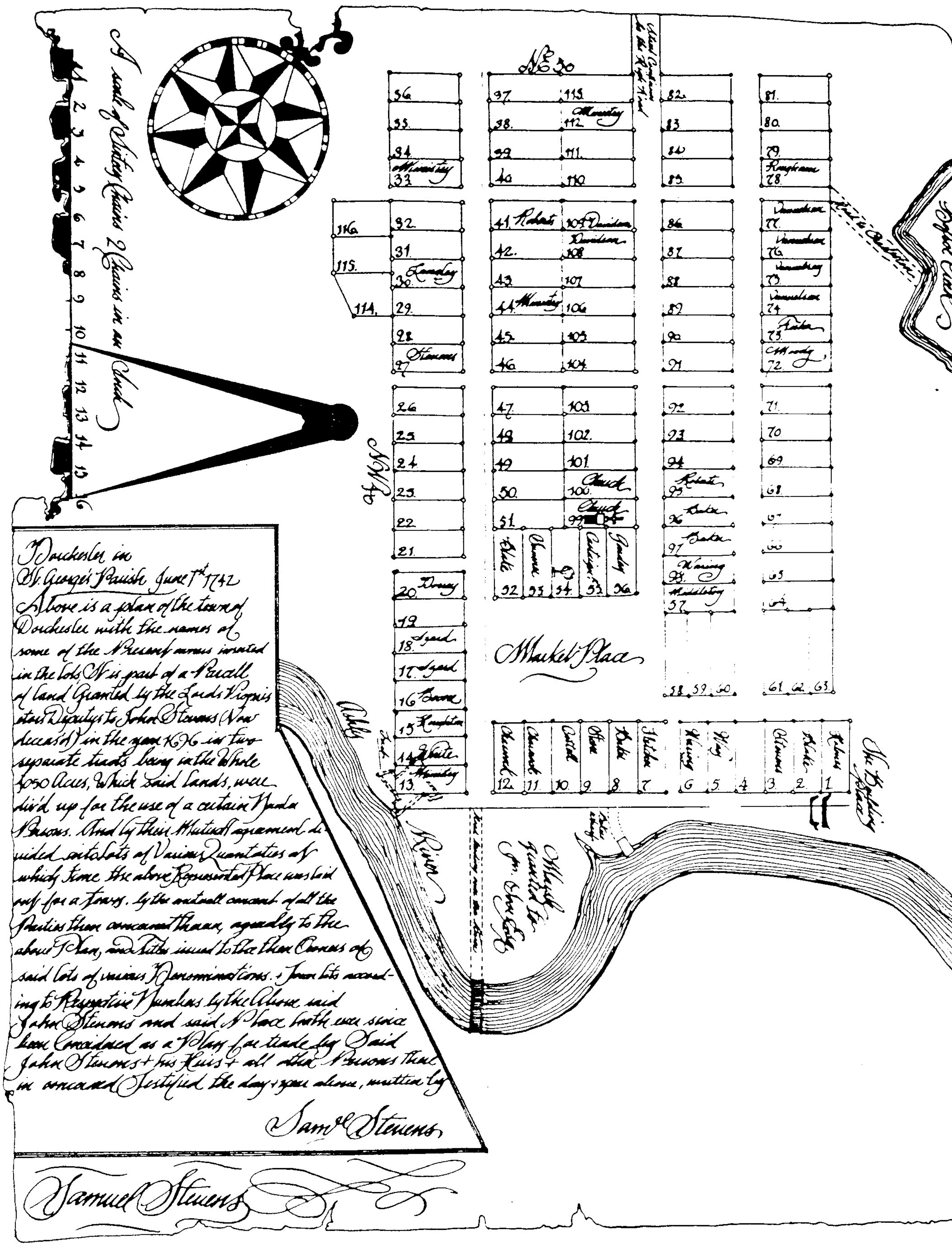
Lots 52, 53, 54, 55 and 56 in the village of Dorchester, about an acre and a quarter, facing the public square, were purchased as a site for the church and church-yard. A glebe of 150 acres within the limits of the Dorchester 4,050 acres was also purchased.

The parish then contained 115 English families, numbering about 500 souls, and 1,300 slaves.

The commissioners appointed by Statute for building the church procured a subscription of £1,196, to which the General Assembly added £466. The work of construction was begun in 1719, and in 1720 all the outer work was finished. The church was of brick, 50 feet long by 30 wide, besides the chancel. In 1724 the glebe and parsonage being found inconveniently distant from the church, by authority given by a Statute, the old glebe and parsonage were sold and a new one purchased. The new glebe was lot 25 in the first range, fronting on Ashley River 50 acres, with 25 acres in the second range—75 acres in all. The parsonage building was on the north side of the public road, about a quarter of a mile west of the church. It is now owned by Mr. John Grimball. Some large oaks and a few wooden buildings mark the site.

In 1734 a Statute was passed reciting that the church was in a very decayed and ruinous condition, and also too small for the inhabitants of the parish, and directing the vestry and church wardens to repair and new pew the church and make an addition to it. In 1736 the repairs had advanced but were not yet finished. In 1739 £300 (currency) was appropriated by Parliament for a parsonage house.

FROM: Smith, Henry A.M., Cities and Towns of Early South Carolina Vol. 2
Spartanburg, SC: The Reprint Company, Publishers, 1988.


Dorchester in
St. George's Parish June 1st 1742
Above is a plan of the town of
Dorchester with the names of
in the lots
which said Lands, were
Quantaties of
said lots of various Denominations.
John Stevens
John Stevens + his Heirs + all other Persons that
Testified the day + year above, written by
Sam^l Stevens
Samuel Stevens
Market Place
River
Church
Ministry

The Old Fort

The old fort that faces the old church stands on the top of the rise or bluff of the river bank where it commanded the bridge across the river and the approach to it. It is located partly on lot 13 in the plan of the old village and partly on the street leading to the bridge head. It is the most perfect example remaining in the State of a fort of the period. It is constructed of the material called "tapia", or more commonly "tabby". This is composed of oyster shells embedded in a bond or matrix of burnt shell lime, and forms a most durable and lasting composition. The exact date of its construction is unknown. The material of its construction gives no certain indication as "tabby" was used for such purposes from an early date in the history of the Province down to as late as 1812.

There is a tradition that the fort was coeval with the settlement of Dorchester, and was relied on as a defence against the Indian enemies of the Province. No record support of this exists, although it is plausible and likely. On the plan of the village as originally laid out in 1697, as afterwards, in 1742, recorded in the office of the Secretary of State, no fort is set down, although the site of the parish church, constructed in 1719, is mentioned. There are a number of appropriations for fortifications in the tax Acts passed by the Assembly from 1740 on, but in none of such as are published in the Statutes at Large is any specific mention made of the fort at Dorchester.

In 1775 the Council of Safety of the Province directed Dorchester to be fortified, and in December, 1775, they directed Fort Lyttelton, near Beaufort, to be repaired with "tappy". Commissioners of fortifications for Dorchester were appointed by the Council of Safety, and in December, 1775, urgency was recommended to them in the erection of barracks, a guard room, and a place for confinement of prisoners; and on January 31, 1776, the Council of Safety authorized the payment of £760.10.07 on account of the fortification of Dorchester, and in February the military stores were placed in the fort and magazine at Dorchester, with a further payment of £271.10.00 on February, 6, 1776, for hire of negroes on the works at Dorchester.

Whatever fort or strong-work may have existed prior to 1775 it is safe to infer that the present fort represents the fortification constructed in that year by order of the Council of Safety.

FROM: Smith, Henry A.M., Cities and Towns of Early South Carolina Vol. 2
Spartanburg, SC: The Reprint Company, Publishers, 1988.