Geology of Port Hudson State Historic Site and National Historic Landmark, and Surrounding Areas

State Parks and Land Series No. 2
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The purpose of this series is to make a variety of geological information for state-owned lands accessible to the public.

Front cover: Digital photograph of the Mount Pleasant Bluff taken by the author from Faulkner Lake (~1 mile to the south) on January 13, 2009.

Back cover: Digital photograph of a drilling rig (Maritech Resources, Inc.) drilling the Tuscaloosa Group above the nearby Irene Salt Dome, East Baton Rouge Parish (LDNR well serial number 240398). Photograph taken by the author on January 31, 2010.

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Geology of Port Hudson State Historic Site and National Historic Landmark, and Surrounding Areas

by:
Thomas P. Van Biersel

Baton Rouge
2011

IN MEMORIAM

This document is dedicated to the memory of F. Ann Tircuit, beloved Administrative Coordinator of the Louisiana Geological Survey at Louisiana State University, who passed away prematurely May 22nd, 2010. She will be missed.

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List of Abbreviations

ac	acre
a.k.a.	Also known as
B.P.	Before present
DOQQ	Digital Orthophoto Quarter Quads
e.g.	exempli gratia (for examples)
Gen.	General
i.e.	id est (that is)
LA	Louisiana
LDEQ	LA Dept. of Environmental Quality
LDNR	LA Dept. of Natural Resources
LDOTD	LA Dept. of Transportation and Development
LGS	Louisiana Geological Survey
LIDAR	Light detection and ranging
LLC	Limited Liability Company
LOSC	LA Office of the State Climatologist
LSU	Louisiana State University
MY	Million years
NAD	North American Datum
NPS	National Park Service
Pimo	Montpelier alloformation
Pph	Hammond alloformation
Ppi	Irene alloformation
NCDC	National Climatic Data Center
TDS	Total dissolved solids
USACOE	U.S. Army Corp of Engineers
USDI	U.S. Dept. of the Interior
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

List of Unit Conversions

Unit	Multiply by	To obtain
inch (in)	2.54	centimeter (cm)
foot (ft)	0.3049	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (m^2)	2.59	square kilometer (km^2)
acre (ac)	0.4047	hectare (ha)
Lieu	~3	mile (mi)
league	~3	mile (mi)
Toise	~6	foot (ft)
gallon/day/$foot^2$ (gal/day/ft^2)	0.055	Darcy (D)
foot/second	0.305	meter/second (m/s)
pound/square foot (lb/ft^2)	0.048	kilopascal (kPa)

List of Unit Symbols

~	approximately
<	less than
>	greater than
-	degree
%	percentage

Introduction

The purpose of this series is to make a variety of geological information for state-owned lands accessible to the public. The subject publication describes the natural history, and more specifically the geology as it applies to the Port Hudson State Historic Site and National Historic Landmark and surrounding area of Louisiana. The descriptions encompass the area of the State Park (Fig. 1), as well as all the areas south of Thompson Creek, east of the Mississippi, north of Lilly Bayou and west of State Highway 61 (Fig. 2).

The State Park/Historic Site and its surrounding areas is one of the first sites to be repeatedly studied by imminent naturalists and geologists during the 18th and 19th centuries. In addition, the site is one of the 45 Civil War sites ranked as a "Class A" site (i.e., "having a decisive influence on a campaign and a direct impact on the course of the war") by the Civil War Sites Advisory Commission of the U.S. Department of the Interior's National Park Service (NPS). Besides its strategic importance in the geography of the Civil War, the Siege of Port Hudson also included the first significant use of uniformed African-American soldiers; in this case the First and Third Louisiana Native Guards (i.e., the Corps d'Afrique) pressed into battle by the Union Army. It was also the longest siege (48 days) in American military history.

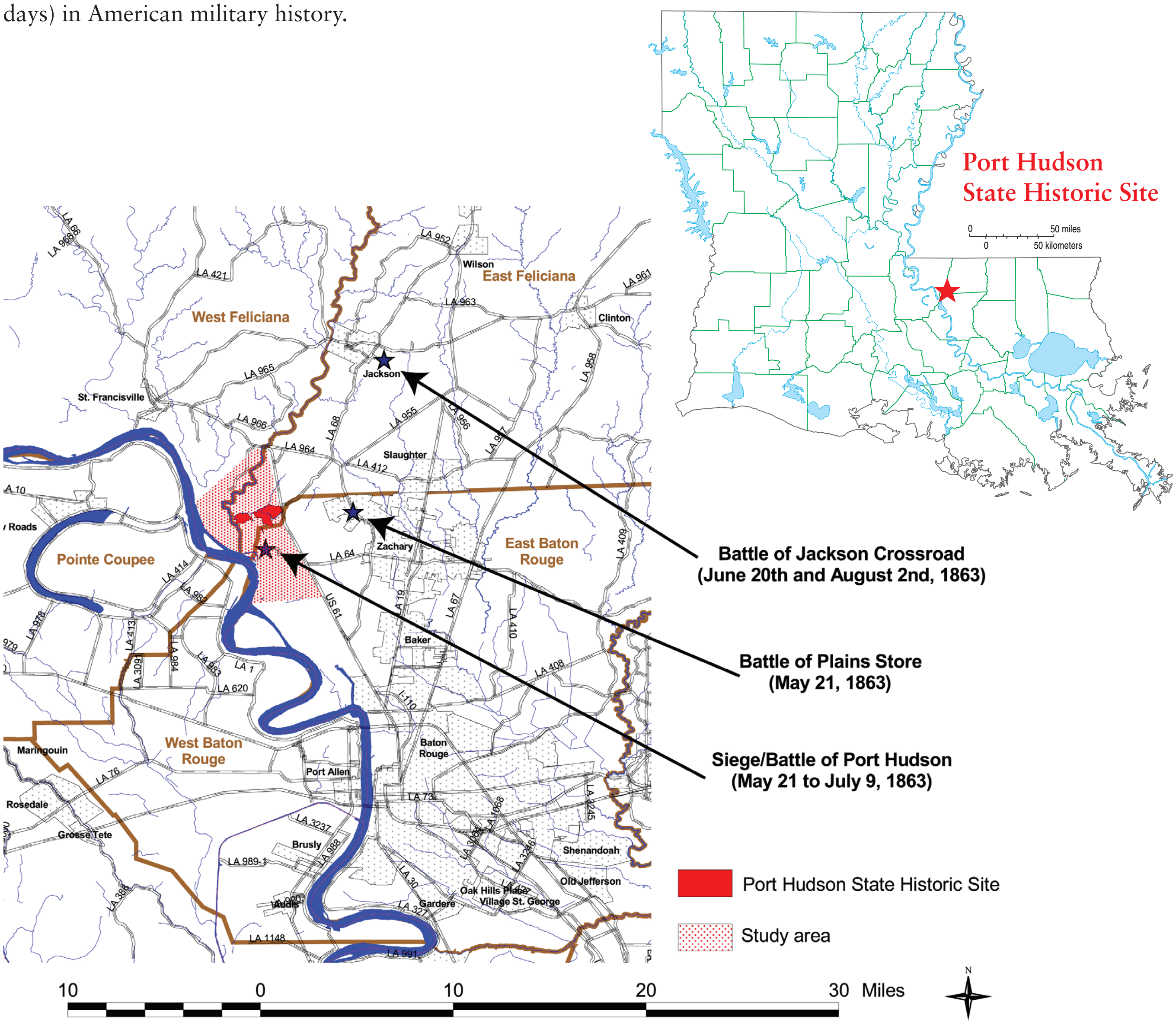


Figure 1: General location map of the Port Hudson State Historic Site and National Historic Landmark (colored in red). The three ★ represent the military engagements associated with the Port Hudson Campaign. This report only discusses the vicinity of the Town of Port Hudson.

In the late 1950s, a group of local citizens took upon themselves to raise awareness of the Port Hudson Battlefield and the need to preserve this historical site. From this group, the Committee for the Preservation of the Port Hudson Battlefield (the Committee) was formed and incorporated in 1962. The site was nominated to the National Register of Historic Places by the Afro-American Bicentennial Corporation in December 1973, and The U.S. Department of the Interior (USDI) designated the area as a National Historic Landmark in 1974. The Port Hudson State Historic Site became part of the Louisiana State Park system in 1982. In 1993, the National Park Service surveyed the remaining earthworks and other features of the battlefield.

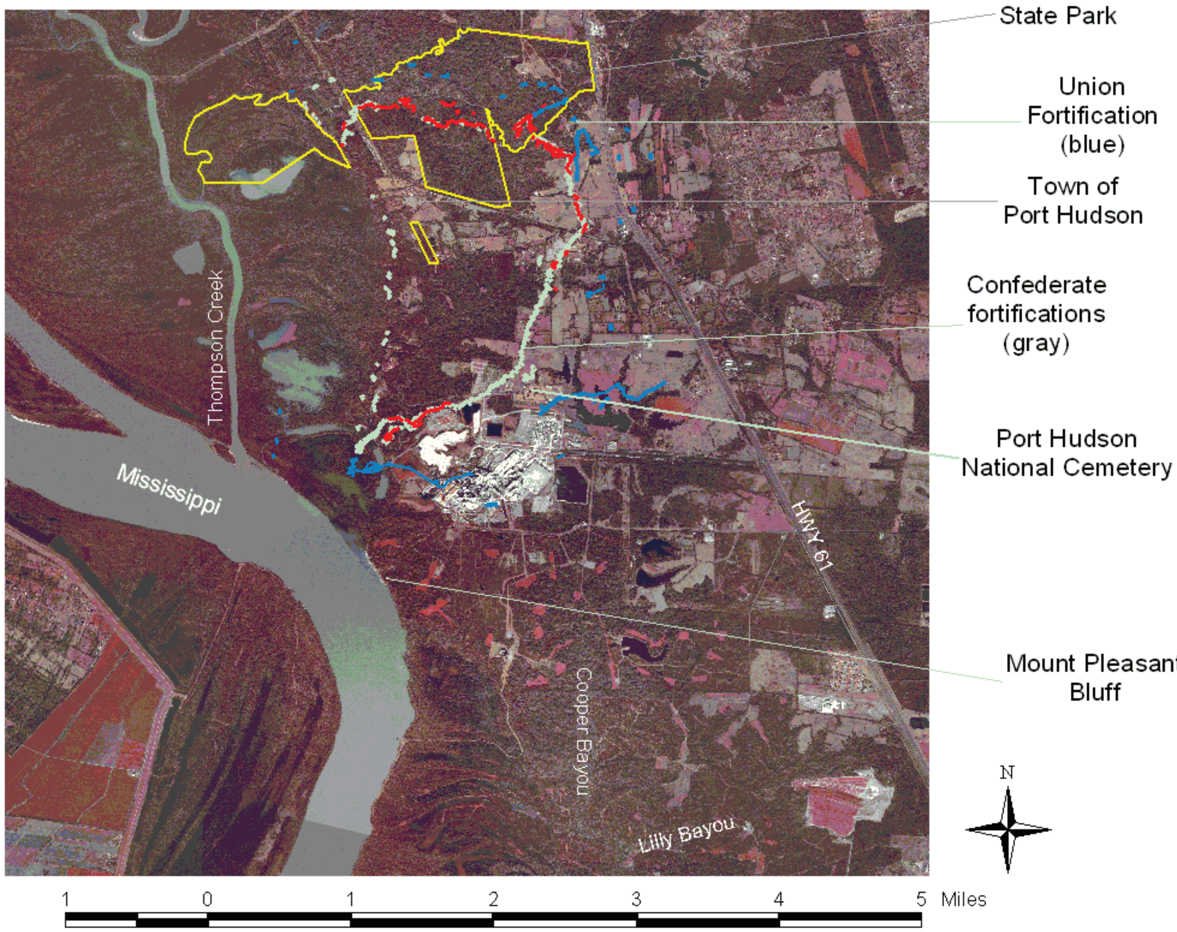


Figure 2: Geographic area covered by the study. The Union and Confederate earthwork locations are derived from Smoot, 1864. Earthwork in red are those still existing today. The base photographs are 2004 Digital Orthophoto Quarter Quadrangle (DOQQ - Atlas, 2008)

Location and Facilities

The Port Hudson State Historic Site and National Historic Landmark (the Park) is located ~20 mi (~32 km) north of downtown Baton Rouge, Louisiana (Fig. 1). The Park is located in East Feliciana Parish, although most of the Port Hudson battlefield and the Town of Port Hudson are located south of the Park in East Baton Rouge Parish (Fig. 1). It is located east of Thompson Creek, a tributary of the Mississippi River and west of U.S. Highway 61. The park is partially bound to the north by Sandy Creek, a tributary of Thompson Creek, and Foster Creek, a tributary of Sandy Creek (Figs. 2 and 3). The Park is composed of three individual land parcels: (1) the largest parcel [~650 ac (263 ha)], which is the Park and is open to the public on a regular basis; (2) a second large parcel [~250 ac (101 ha)], located beneath the bluff, and within the Thompson Creek and Mississippi River floodplains, which is accessible only with special permission from the Park Manager; and (3) a smaller parcel [~10 ac (4 ha)] in Port Hudson, which is not open to the public.

The Park has ~6 mi (~10 km) of trails (orange lines on Fig. 3), a museum and visitor center (e.g., interpretive center - #6 on Fig. 3), three observation towers, a battlefield (#10 on Fig. 3), a picnic area (#9 on Fig. 3), and public restrooms. The trail starts at the Fort Desperate parking lot (#7 on Fig. 3) and the park's visitor center (#6 on Fig. 3). The 6-mile long trail meanders through the Park with interpretive stops at six locations: Fort Desperate (#1 on Fig. 3); the Alabama/Arkansas Redoubt (#2 on Fig. 3); the Bennett Redoubt (#3 on Fig. 3); the Commissary Hill (#4 on Fig. 3); the Mississippi Redoubt (#5 on Fig. 3); and Fort Babcock (#8 on Fig. 3). The trails generally run along the crests of ridges, however Foster Creek is crossed in one place.

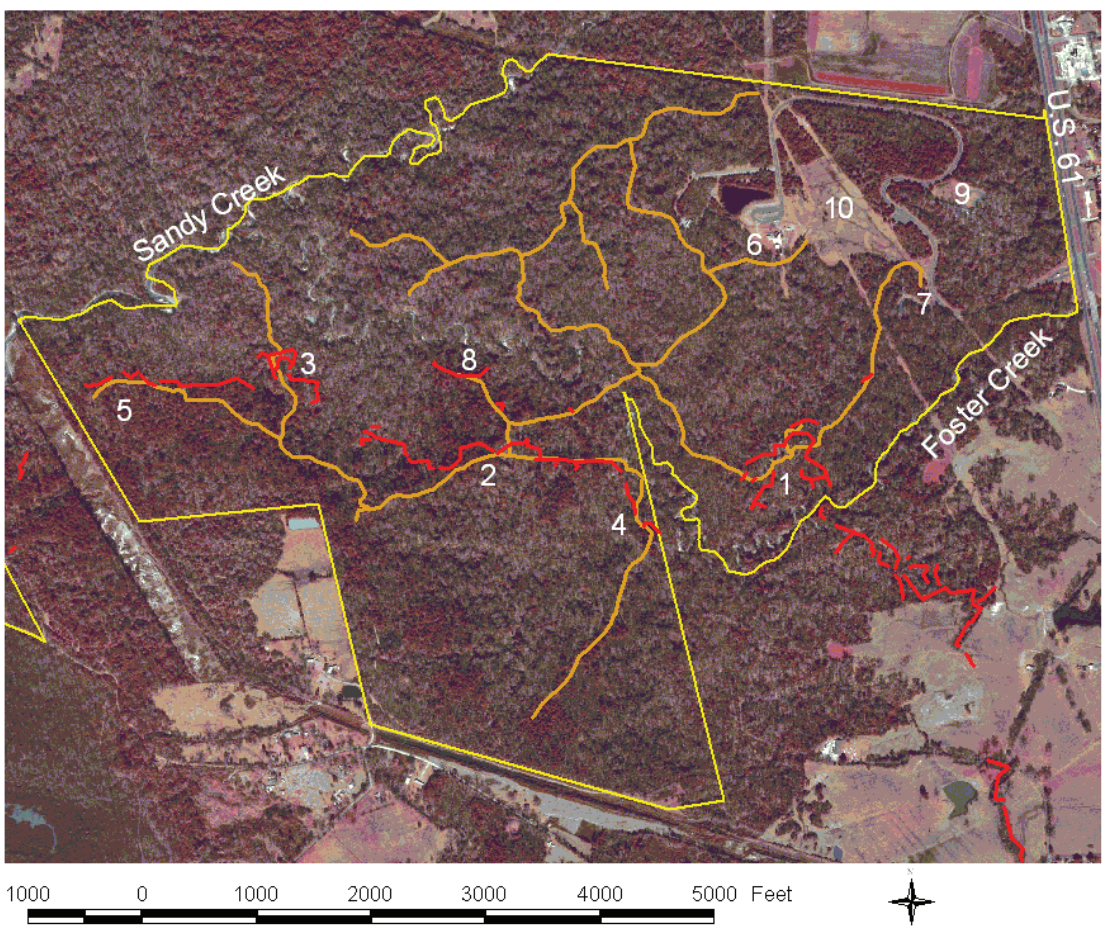


Figure 3: Port Hudson State Historic Site map (largest land parcel of the Park). The yellow lines are the boundary of the Park; the orange lines are the hiking trails; and the red lines are the existing earthworks. The base photograph is a 2004 DOQQ (Atlas, 2008).

At the peak of its fortification, Port Hudson was surrounded by 5.9 mi (9.5 km) of earthworks in a half-moon shape (Fig. 2), starting to the north where Sandy Creek cuts the bluff and ending at Devil's Elbow, where Sherburne's Bayou cuts the bluff north of the Mount Pleasant bluff (Fig. 5). Based upon a 1993 survey by the National Park Service, approximately 2.4 mi (3.9 km) of earthworks remain, in various conditions. The fortifications were nearly continuous, except to the north, where steep ravines associated with Sandy and Foster creeks provided a natural defense (Fig. 4). There were three available entry points into the fortifications: (1) through a sally port (i.e., opening/gap in the earthworks to allow for passage) on the Jackson Road; (2) through a sally port (i.e., opening/gap in the earthworks to allow for passage) on the Plain Road; and (3) following the Telegraph Road (road to Bayou Sara) along the base of the bluff to the Port Hudson Landing. The Telegraph road and a portion of the Jackson Road remain, but are on private properties. The Port Hudson-Plains Road (called West Port Hudson-Plains Road west of U.S. 61) is still in use.

The Park hosts a Civil War reenactment every March. The reenactment spans an entire weekend, and takes place on the park's battlefield (#10 on Fig. 3). A reenactment also takes place in nearby Jackson, Louisiana, in April. The Civil War battle of Plains Store (May 21, 1963) at the onset of the siege of Port Hudson and the battle of Jackson Crossroads (June 20th and August 3, 1863) after the surrender of Port Hudson (July 9, 1863) are, as indicated, related to the battle for Port Hudson and the campaign to control the Mississippi River. They, however lie outside the geographic area of this study, and therefore are not treated here.

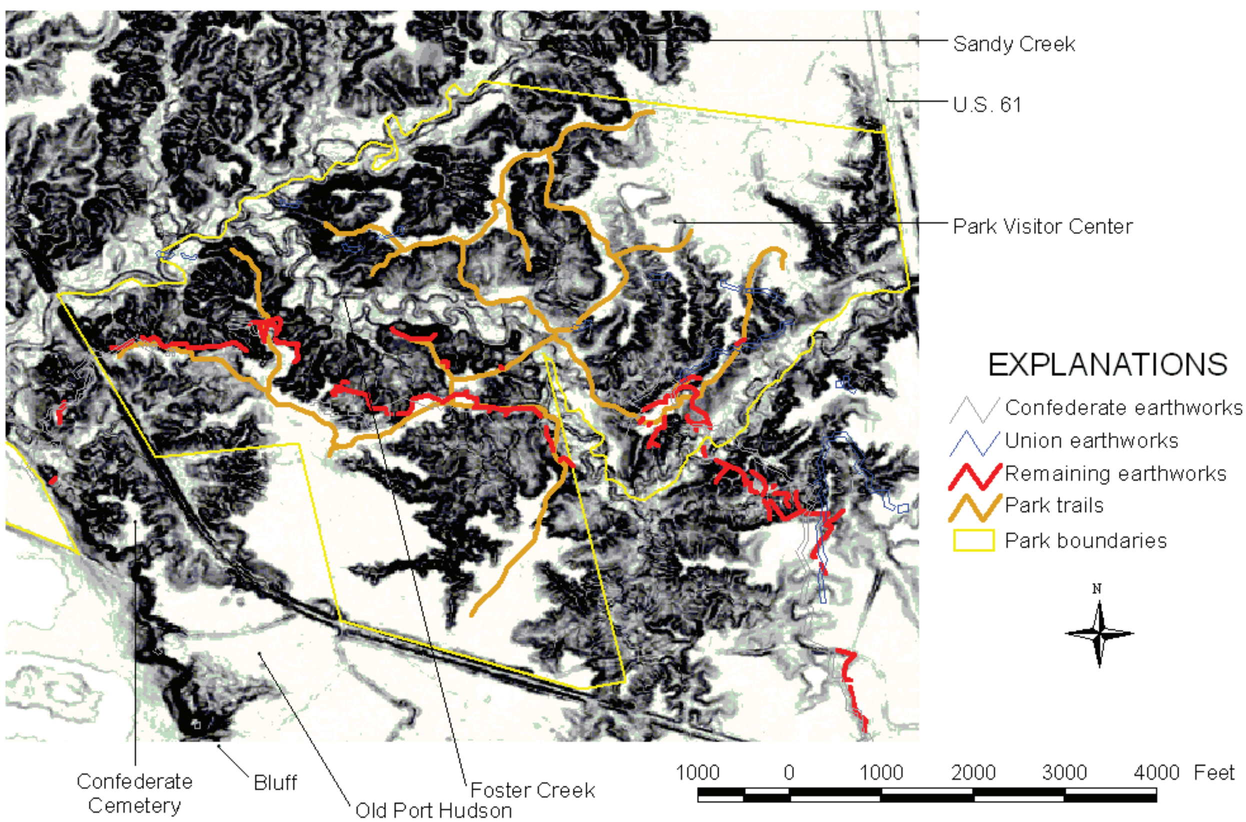


Figure 4: Topography of the Port Hudson State Historic Site (largest land parcel of the Park). The yellow lines are the boundary of the Park; the orange lines are the hiking trails; and the red lines are the existing earthworks. The base map is a light detection and ranging (LIDAR) image (Atlas, 2008) shaded using Global Mapper's slope shader.

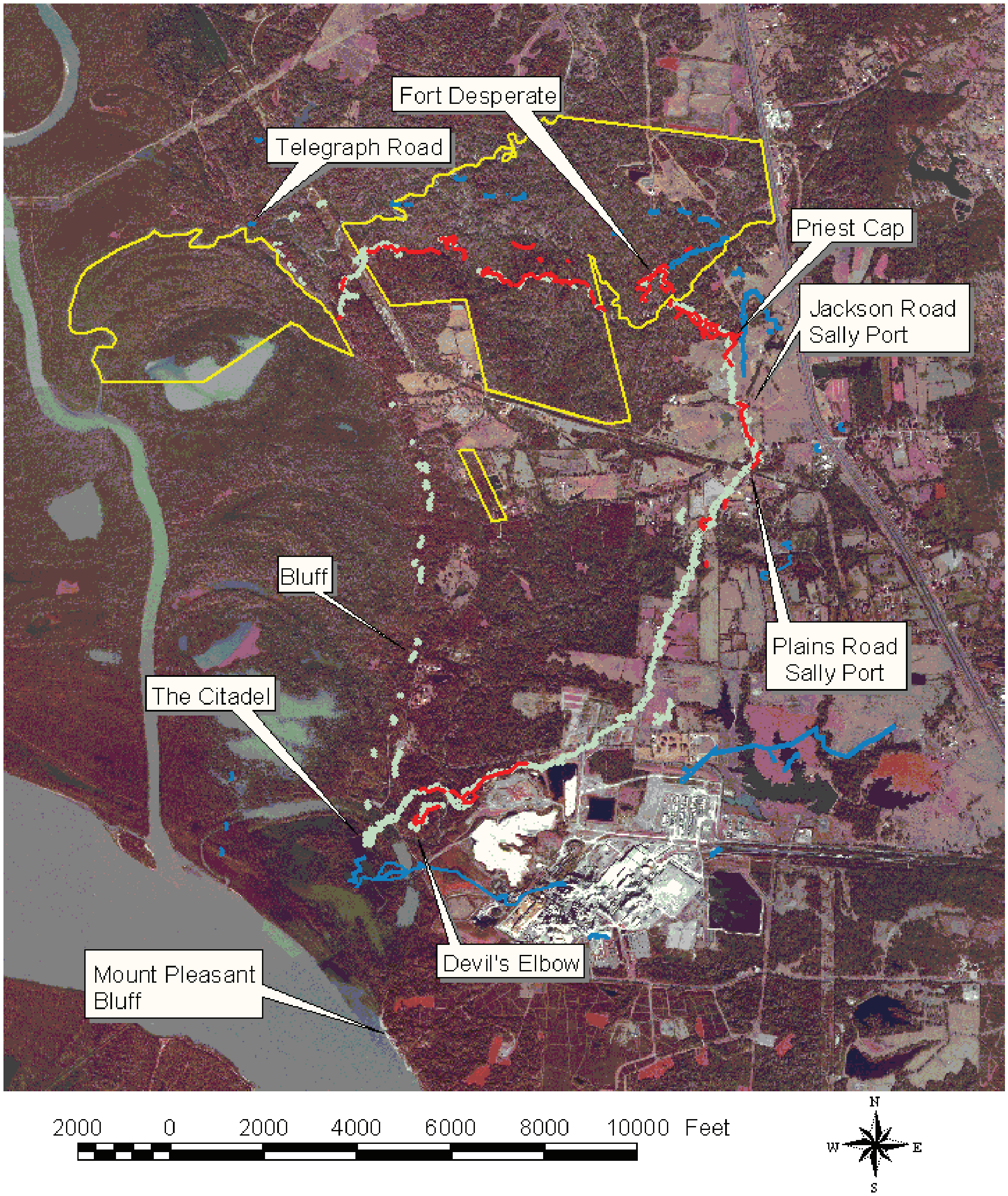


Figure 5: Location of significant features of the Confederate earthworks (gray color). The red lines show the earthwork remaining in 1993. The blue lines are Union Earthworks. The base photograph is the 2004 DOQQ (Atlas, 2008)

Brief History

A chronology of important dates is included in Table 1. Specifically, the table lists the important events in this area of Louisiana that makes it significant to earth sciences and history.

Early America/Pre-American Civil War

The bluffs between Port Hickey (Mt. Pleasant bluff) and Port Jackson (located at the mouth of Thompson Creek) were initially carved when the Mississippi River flowed through its ancestral cut-off meander, known today as False Lake and Pointe Coupée, and "*Fausse Rivière*" in the past (Figs. 1 and 2). The bluffs have had many names including "*écores blanc*' (maps by Lafarge, 1768 and Lafon, 1806) and "*écores au lait*" by French explorers, and "*Milk Cliffs*" (map by Romans, 1781) and "*Browne's Cliff*" (map by Gauld, 1778) by the British explorers.

The area, and, more specifically, the loess bluffs along the Mississippi River north of Baton Rouge, Louisiana (Figs. 1 and 2) were first documented by the members of René-Robert Cavelier Sieur de La Salle's expedition. The expedition viewed the bluffs in late March 1682 upon their descent of the Mississippi from St. Louis, Missouri. Nicolas de La Salle, a member of the expedition, writes in his journal:

"Le lendemain on fit 12 lieuès á moitié chemin
on vit des montagnes sur la gauche at une rivière
qui en sortois on la nomma la rivière
aux risqué, on cabana en pays noyé á l'ordinaire."

The following day we traveled 36 miles (from the mouth of theRed River); halfway we saw mountains to the left with a river flowing out of them; we named it the "rivière aux risqué" [risky (e.g., taking a chance or subject to peril) river]; we camped in flooded country as usual. (translation by the author)

It is likely that he is referring to Thompson Creek, although Bayou Sara might also fit the description as well. The surviving members of the retreating expedition of Hernando De Soto were most likely the first Europeans to see the bluffs in July, 1543. Their journal makes note of an Indian village on a high bank, possibly referring to the bluffs near Natchez, Mississippi, where the Sieur de La Salle expedition also observed villages. It should be noted that there are few descriptions of the bluff by explorers traveling down the Mississippi. Descriptions are more common from travelers moving up the river, as the bluffs are light in color, and the first high ground observed after several days travel.

On March 18, 1699, the Sieur Pierre Le Moyne d'Iberville expedition reached the bluff which he described as follows:

"The 18th. My brother and the Indians overtook me, the Indians having killed nothing; my brother killed one bear. Two leagues from our last camp I found an island 1 league long, the first one that I have discovered in the river. Two leagues from the island, on the right side, I found high ground rising 50 feet straight up-sandy land for 2 leagues, like at Étampe; the other bank was flat like everywhere else. Six leagues and a half from our last camp we found a creek 6 feet wide that runs out of the Myssysypy River. The Indians told me that, if I could get my longboats through it, I would shorten my journey by one day's travel. I sent my brother by canoe to see whether that was possible. He told me that it could be done with a little work. There is a distance of 500 yards where I found a

raft of trees 30 feet high that the high waters had piled on top of one another, blocking the way through. I put the men to work to clear a way 350 yards long and made the portage with everything I had in my longboats; and with pulleys I had the boats dragged from the other side and launched on the river, after a great effort, owing to the rain and the muddy ground, on which one could not keep his footing."

(Le Moyne d'Iberville and McWilliam, 1991)

A member of the expedition, François Surgères, Marquis de la Rochefoucauld, writes in his journal that upon reaching what is now Pointe Coupee, the Indians:

"nous montrèrent une petite rivière dont l'eau ne courraient point, par laquelle ils nous disaient que nous eussions abrégé notre chemin de plus d'une journée et demie. M. d'Iberville s'embarqua dans un petit canot d'écorce pour voir s'il y avait lieu d'y passer n'y ayant que quelques arbres qui bouchaient le passage, il fit mettre tout les Canadiens avec des haches à terre et le reste à hâler avec des cordes les chaloupes. On fit un chemin en applanissant la terre le plus qu'on put."

they showed us a small river whose water was not flowing, by which we were told that we shortened our travel by more than one and a half day. Mr. D'Iberville climb into a bark canoe to see if it was passable, since only a few trees blocked the entry, he made the Canadians disembark with axes and the rest to haul with rope the longboat. We made a pass by flattening the earth as much as possible

(translated by the author)

This statement, as well as others from French travelers, suggests that the development of False Lake cut-off meander was facilitated by early French explorers. The first documented clearing occurred in 1699, during the Sieur d'Iberville 1699 expedition, when the cut-off channel was apparently 500 yards (457 m) long. Another clearing occurred in 1713, when Mr. Le Page du Pratz documented that two travelers cleared again, and deepened the channel, which by then was only 600 (183 m) feet long. Mr. Le Page du Pratz indicated that the cut-off channel was well-established by 1719.

In 1777, William Bartram, a botanist, visited the bluff at Port Hudson. In his journal entries he described a "fossil forest" at the base of the Mount Pleasant bluff. Mr. Bartram includes in his journal the following description:

Next morning we sat off again on our return home, and called by the way of the Cliffs, which is a perpendicular bank or bluff, rising up out of the river near one hundred feet above the present surface of the water, whose active current sweeps along by it. From eight or nine feet below the loamy vegetative mould at top, to within four or five feet of the water, these cliffs present to view stratas of clay, marle and chalk, of all colours, as brown, red, yellow, white, blue and purple; there are separate strata of these various colours, as well as mixed or particoloured: the lowest stratum next the water is exactly of the same black mud or rich soil of the adjacent low cypress swamps,

above and below the bluff; and here in the cliffs we see vast stumps of cypress and other trees, which at this day grow in these low, wet swamps, and which range on a level with them. These stumps are found, stand up-right, and seem to be rotted off about two or three feet above the spread of their roots; their trunks, limbs, &c. lie in all directions about *them. But when these swampy forests were growing, and by what cause they were cut off and overwhelmed by the various strata of earth, which now rise near one hundred feet above, at the brink of the cliffs, and two to three times that height but a few hundred yards back, is a phenomenon perhaps not easily developed; the swelling heights rising gradually over and beyond this precipice are now adorned with high forests of stately Magnolia, Liquid-amber, Fagus, Quercus, Laurus, Morus, Juglans, Telea, Halefia, Aesculus, Callicarpa, Liriodendron,&c.*

(Bartram, 1791, p. 435-436)

Evidence of research at the bluffs was first published in 1839 by Prof. William Carpenter of the Jackson College, Jackson, Louisiana. Prof. Carpenter reports his observation of bituminous deposits at the base of the Mount Pleasant bluff (Fig. 6). He identifies those as remnants of an extensive buried forest. He reports from eyewitnesses accounts that the bluff had retreated at that locality more than 400 yards (366 m) since the area was settled.

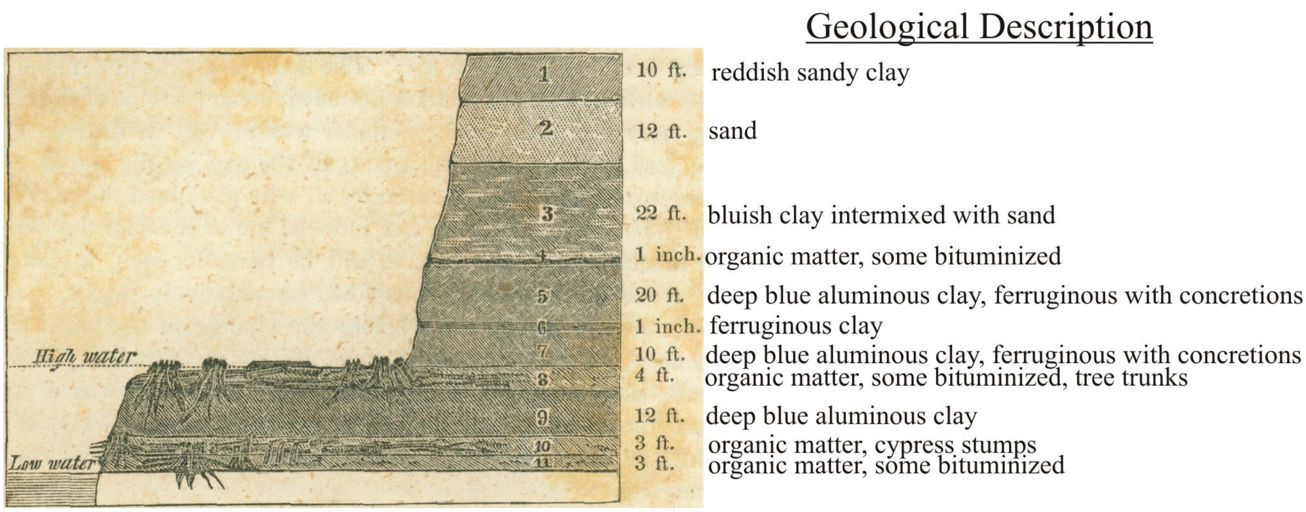


Figure 6: Description of the bluff geology at Port Hudson (source: Carpenter, 1838; courtesy of Special Collections, Louisiana State University).

In the 19th century, Sir Charles Lyell (one of the fathers of modern Geology) reported in his journal that he had stopped by the bluffs. Lyell stopped at the suggestion of Prof. Carpenter, and after hearing of Bartram's fossil forest and a floating island in Solitude Lake south of the Mount Pleasant bluff. Sir Charles Lyell goes on to state:

"I afterwards proceeded to examine that part of the cliff which extends about a mile down the river's left bank, immediately below Port Hudson, where it is between seventy and eighty feet high. The deposits laid open to view were divisible into three groups, the topmost consisting of brown clay, the middle of whitish siliceous sand,

and the lower of green clay. I found some men digging the middle or sandy stratum for making bricks, and they had just come upon a prostrate buried tree, black and carbonized, but not turned into lignite... At this point they told me that the bluff has, in the course of the last eight years, lost ground no less than 200 feet by the encroachment of the river..."
(Lyell, 1855, p. 181-182).

He goes on, concluding that:

"I have dwelt at some length on the geological phenomena disclosed in the interesting sections of these bluffs, because I agree with Bartram and Carpenter, that they display a series of deposits similar to the modern formations of the alluvial plain and delta of the Mississippi. They lead us, therefore, to the important conclusion, that there have been changes in the relative level of land and sea since the establishment, in this part of the continent, of a geographical state of things approximating to that now prevailing...

Although I could not ascertain the exact height above the level of the sea, of the fossil cypress swamp at Port Hudson, I presume it is less than thirty feet; and in order to explain the superposition of 150 feet of freshwater sediment, we must imagine the gradual subsidence of fluviatile strata to a depth far below the level of the sea, followed by an upward movement to as great an amount."
(Lyell, 1855, p. 183)

Sir Charles Lyell was interested in a material called "loess," which had been identified and named earlier in the Rhine region of Germany by scientists there. Loess is a fine-grained aeolian (e.g. wind-born) deposit predominantly associated with glaciers and deserts. At Port Hudson, Sir Charles Lyell observed this type of deposit, and it is likely that this is the first use of the term in the U.S. by a geologist documenting a glacial deposit.

These historical observations document the rapid migration of the Mississippi River meander near Port Hudson, after the cut-off at Pointe Coupee was completed by the river with the help of native inhabitants, travelers and early settlers. The opening of the cut-off resulted in the silting of the old channel, and the formation of False Lake in Pointe Coupee Parish (west of the river). Another result was the straightening of the Mississippi River channel (Fig. 7), causing the abandonment of several landings (Fig. 8), and the severe erosion of the bluff at Mount Pleasant.

American Civil War

During the Civil War (1861-1865) the control of the Mississippi River became an important target of the Federal (i.e., Union) Armies. Federal Army Gen. Winfield Scott designed a plan to economically and militarily defeat the confederate South. This plan, caricatured at the time by the press as the "Anaconda Plan" (Fig. 9), included gaining the control of the Mississippi River and blocking access to confederate ports. By securing the river for the Union, Gen. Scott, with the approval of Pres. Abraham Lincoln, would geographically split the Confederacy in two and block a resupplying artery for the Confederate Armies.

In order to maintain control of the Mississippi River and its confluent, the Red River, the Confederate Army had garrisons positioned at New Orleans, Baton Rouge, Natchez and Vicksburg. Initially started in April, 1862, to protect New Orleans from an attack from the north (at the recommendation of Gen. Pierre Beauregard), the fortifications at Port Hudson were finally completed to protect Vicksburg from the south, after the fall of

New Orleans and Baton Rouge in May, 1862. Port Hudson became the "Gibraltar of the Lower Mississippi." Similar to Vicksburg (known as the "Gibraltar of the Confederacy"), Port Hudson was located on a bluff overlooking a sharp meander of the river (Fig. 10 and Appendix A). Ships maneuvering in the meander bend had to reduce their speed, and travel the deeper part of the channel located along the bluffs. This exposed them to the fortified batteries above (Fig. 10 and Appendix A) and prevented them from returning fire.

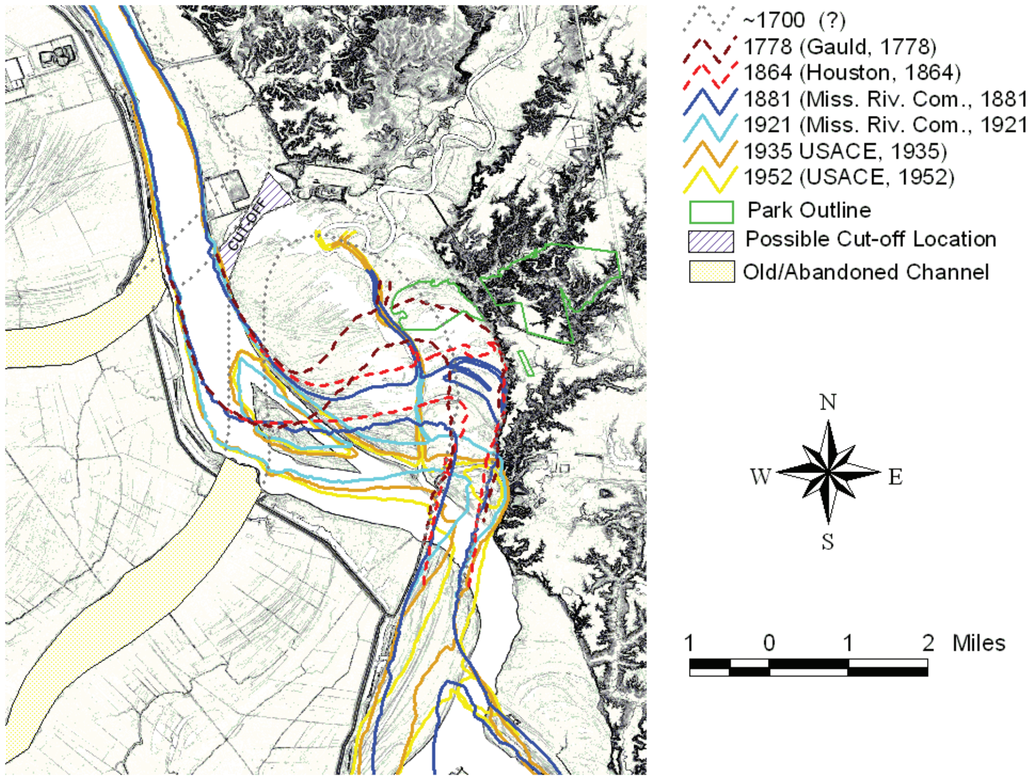


Figure 7: Locations of the Mississippi River channel over time. The source of the meander traces are listed in the explanation. The 1700 trace was estimated by the author based on the bluff morphology and description by French explorers. The base map is a light detection and ranging (LIDAR) image (Atlas, 2008) shaded using Global Mapper's slope shader.

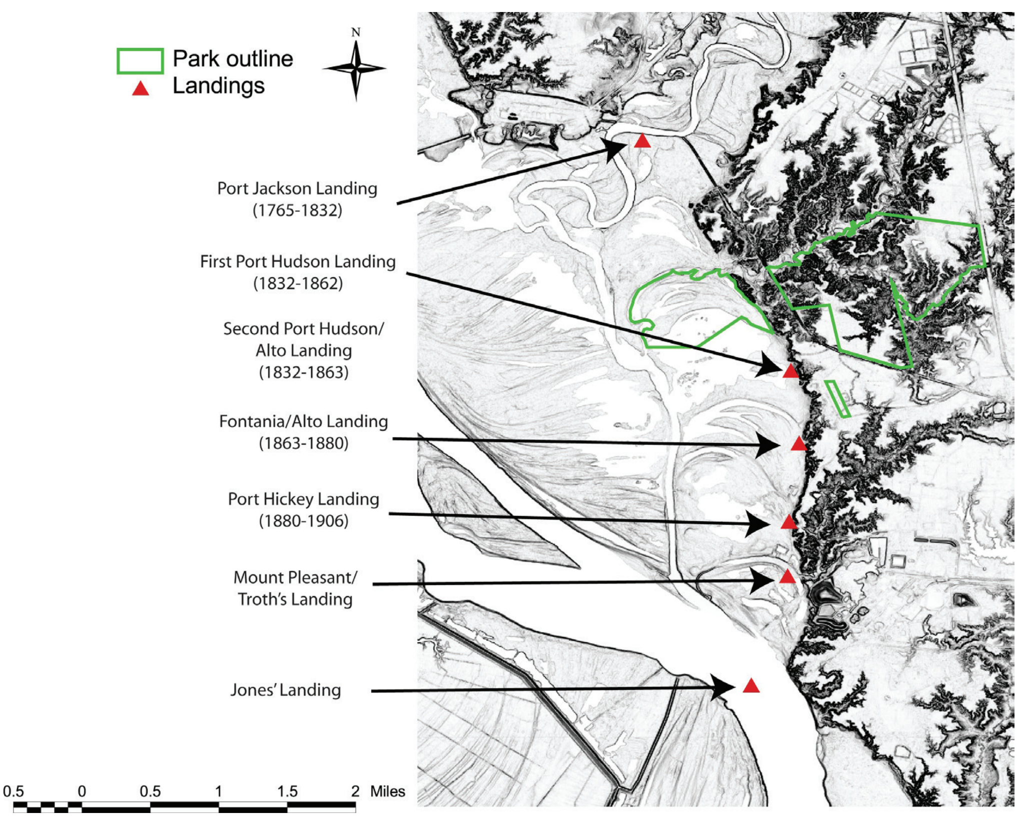


Figure 8: Locations of the Mississippi River landings over time. The location given to Port Hickey and Mount Pleasant are those of 1883. The 2nd Port Hudson and Fontania landings are also referred to as the Alto Landings. The base map is a light detection and ranging (LIDAR) image (Atlas, 2008) shaded using Global Mapper's slope shader.

Table 1: Historical Chronology

<1700	Inhabited by the Houma Indians (Muskhogee Tribe)
1700>	Inhabited by the Tunica Indians
July 1543	De Soto's men pass the bluffs on their way down the Mississippi
Late March 1682	The Sieur de La Salle and member of his expedition view and comment in their journals about the bluffs
Mar. 18, 1699	The Sieur d'Iberville expedition reaches the bluffs and clears the cut-off channel at Pointe Coupee
~1713	Two southbound travelers open up and deepen the cut-off channel which is less than 100 toises (<600 feet) long
~Nov. 1719	Le Page du Pratz observes that the cut-off channel is wide open
~1721	Area is part of the French concession to Mr. de Mezieres
~1763	Port Jackson is built a short distance up the mouth of Thompson Creek (known to the Spaniards as "Rio de la Feliciana" and the French as "Bayou des Grand Remoux").
~1768	Former British Lieutenant Governor Montfort Browne receives the area as part of a large land grant. The bluffs briefly are known as "Browne's Cliffs."
1776	The land is granted to Daniel Hickey by the Spanish Government.
1777	William Bartram makes note of the buried cypress at the Mt. Pleasant Bluff.
Mar. 9, 1804	The U.S. purchases the Louisiana territories from France.
~1832	Port Jackson is abandoned.
~1832	The town and landing of Port Hudson is incorporated and built
~1833	The Port Hudson-Clinton railroad is built
July 1839	Carpenter publishes a detailed geological description of the bluffs.
Mar. 11, 1846	Sir Charles Lyell visits and describes the Mount Pleasant Bluff
1862	The Port Hudson landing is moved south due to the migrating Mississippi River
Aug. 1862	The Confederate Army begins fortifying the bluff at Port Hudson
May 21, 1863	Battle of Plain Store
May 23, 1863	The siege of the confederate fortification at Port Hudson begins
May 27, 1863	First assault of the Port Hudson fortifications by the Federal forces First use of the Louisiana Native Guard of the Corps d'Afrique in battle
June 14, 1863	Second assault by Union forces against the confederate fortifications
July 8, 1863	Cessation of the hostilities at Port Hudson
July 9, 1863	The Confederate forces surrender and Union forces take control of Port Hudson
Aug. 3, 1863	Battle of Jackson Crossroad takes place
Late Summer 1863	The Federal Government fortifies Port Hudson and converts it into a training camp for native troops
~1866	The Union Army abandons Port Hudson
~1872	The Port-Hudson-Clinton railroad is extended to Port Hickey
~1876	The landing of Port Hudson is moved downstream to Port Hickey
~1889	The railroad is abandoned between Ethel and Port Hickey
~1957	The Committee for the Preservation of the Port Hudson Battlefield is established
Dec. 30, 1965	The State of Louisiana purchases 640 acres of the battlefield.
Dec. 1973	Port Hudson is nominated to the National Register of Historic Places
May 30, 1974	The Port Hudson battlefield is designated by the U.S. Department of the Interior as a "National Historic Landmark."

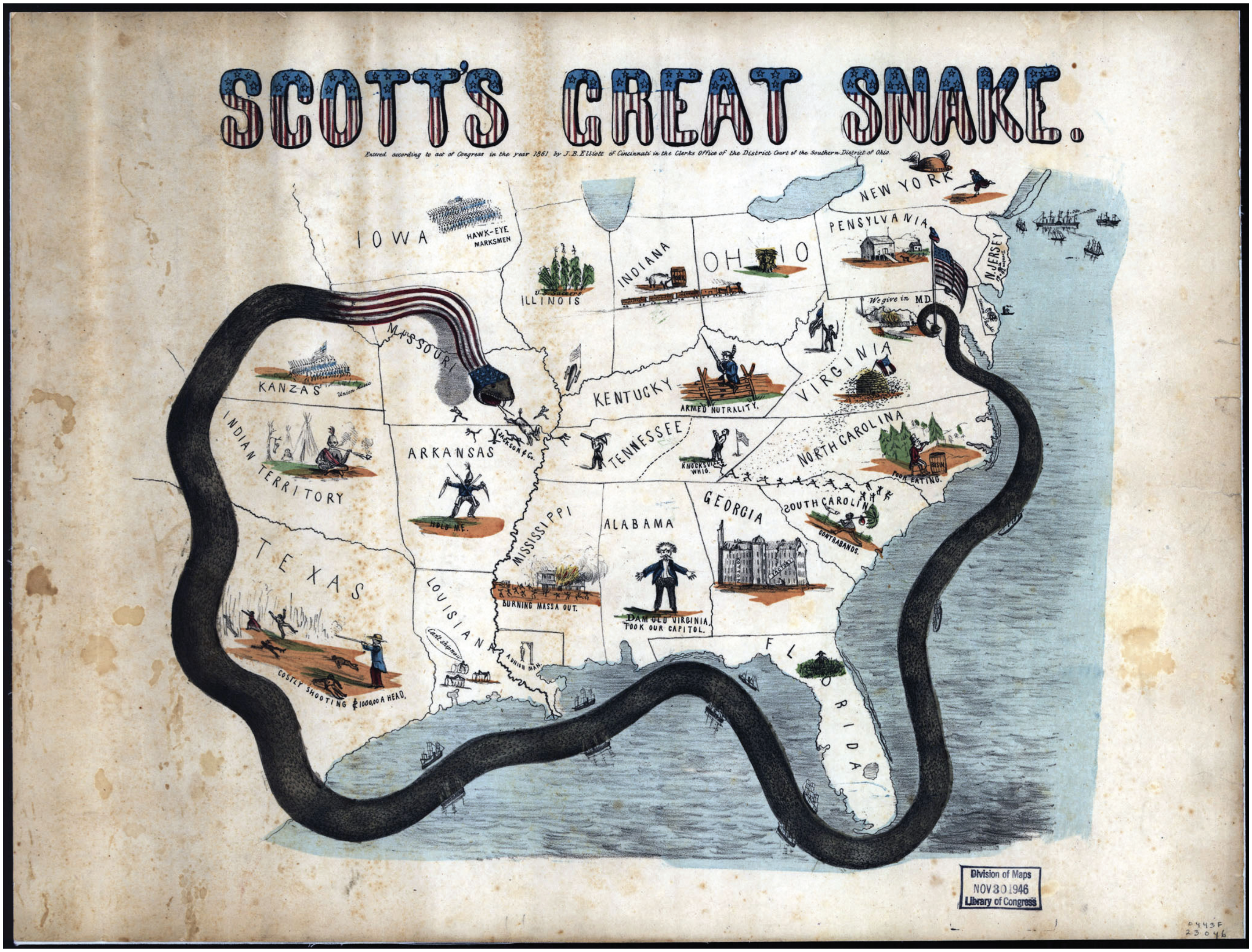


Figure 9: Scott's Anaconda Plan (from Elliott, 1861; source: Library of Congress)

Starting in April, 1862, earthworks were built at Port Hudson in a half circle that encompassed the Port Hudson and Port Hickey landings (Figs. 8 and 10; and Appendix A). A garrison of 2,500 to 2,800 soldiers arrived at the fortification on August 15th, 1862. The first skirmish at Port Hudson occurred on August 29th, 1862, when the Union steamer Anglo-American exchanged cannon volleys with Confederate gunners. By August 31, 1862 the Confederate garrison at Port Hudson was reduced to approximately 1,000 soldiers under Gen. Daniel Ruggles. The Union naval attack on Port Hudson began on November 16th, 1862, with a bombardment of the Confederate position. Another bombardment occurred on December 13th, 1862, and continued sporadically. In December, 1862, the Confederate garrison at Port Hudson changed command from Gen. William Beall to Gen. Franklin Gardner, an engineer by training. The garrison consisted of approximately 5,500 men. During the next three months, Gen. Gardner substantially redesigned the smaller isolated lunettes into continuous lines of earthworks with abatis (i.e., lines of fallen trees used as a barricade) defenses. By the end of March 1863, the garrison at Port Hudson grew to approximately 16,000 soldiers, and included approximately 20 heavy guns along the bluff and another approximately 70 lighter guns scattered along the defenses. By late April, 1863, the garrison was reduced to approximately 11,700 soldiers (8,600 infantry, 1,700 artillery, and 1,400 cavalry), again as troops were diverted toward Vicksburg. By May, 1863, the garrison at Port Hudson was reduced to approximately 6,800 soldiers. In comparison, Union Gen. Nathaniel Banks had approximately 32,000 men and the fleet of Union Admiral David Farragut under his command (Table 2).

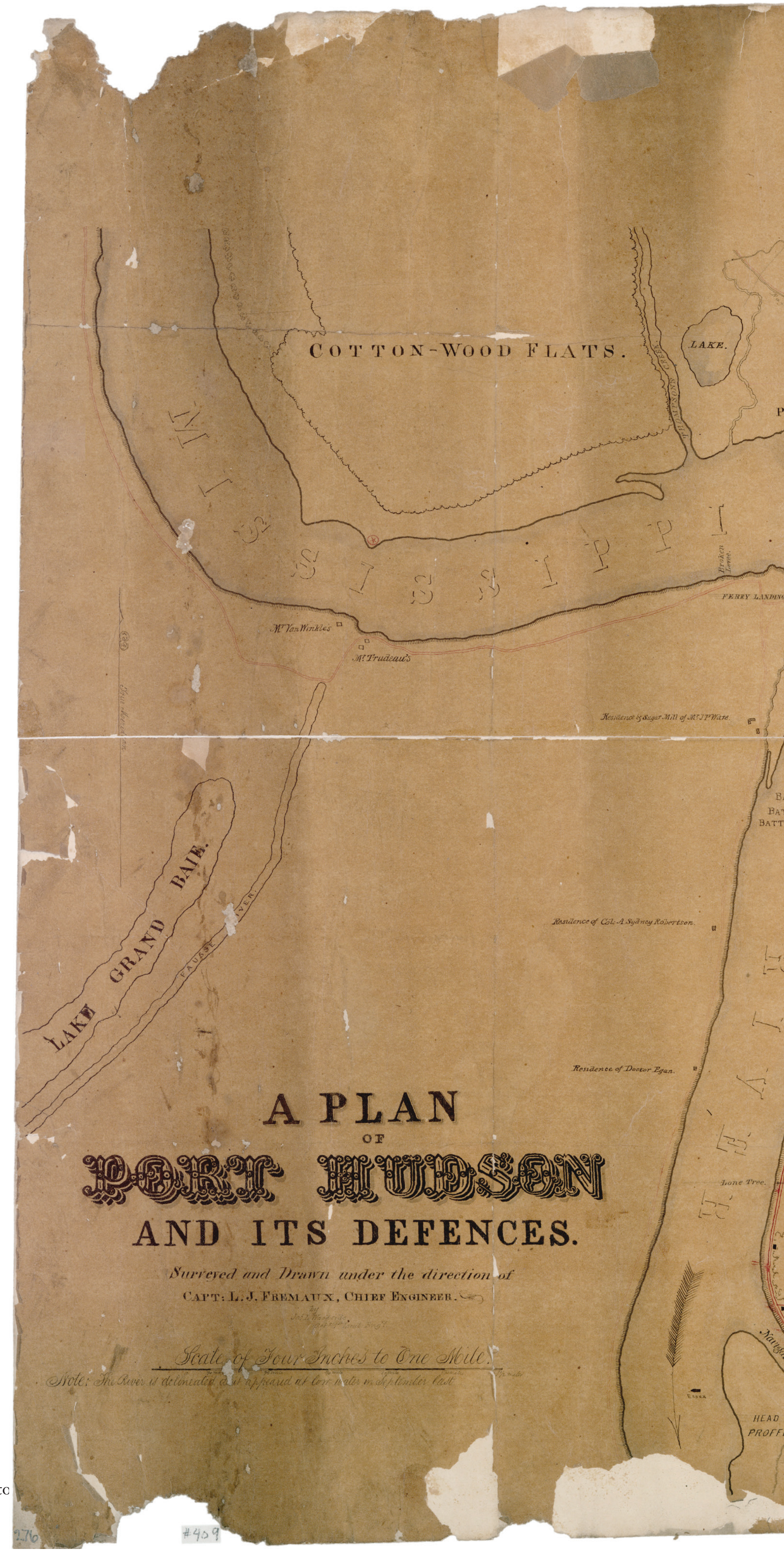
The main phase of the siege of Port Hudson began in March, 1863. On March 14th, 1863, a Union fleet of seven ships, under the command of Admiral Farragut, sailed up the Mississippi River, with the intent of bombarding Port Hudson and moving north to attack Confederate supply ships coming down the Red River. Of the seven ships only the USS Hartford and USS Albatross were able to sail upstream. The USS Richmond, USS Monongahela, USS Kineo and USS Genesee were badly damaged, and the USS Mississippi destroyed. In May, 1863, as the remainder of the Confederate garrison at Port Hudson was ordered to Vicksburg, Gen. Banks moved to encircle the fortifications. On May 20th, the first fighting occurred. By May 23rd, the Confederate garrison was completely encircled, and unable to move north to Vicksburg.

The first main Union attack on Port Hudson began on May 27th, 1863 (Fig. 11). The planned attack on all fronts, including naval bombardment, was marred by confusion and lack of coordination on the Union side. At daybreak, Gen. Augur and Sherman's artillery and Admiral Farragut's fleet opened fire, while Gen. Weitzel's troops attacked from the north through steep ridges and gullies. As Gen. Weitzel's troops were stopped, Gen. Paine began his attack, which also was repulsed by Col. Steedman's troops behind their earthworks. Similar attacks by Gen. Grover's troops and Gen. Dwight's Louisiana Native Guards followed, and were forced back. These sequential and uncoordinated attacks through difficult terrain were repulsed by the greatly outnumbered Confederates, and lasted approximately three hours. By early afternoon, Gen. Sherman's troops and later Gen. Augur's troops began to engage the Confederate troops. However, all the delays had enabled the Confederate troops to rearrange their soldiers' assignments to respond to the individual attacks. By 6:00 p.m., the battle was over, and the status quo remained, Port Hudson had held; however the two armies had combined losses (killed, wounded and missing) of around 2,300 men (Confederate losses were estimated at <300).

During the ensuing siege, the Union artillery and fleet bombarded the Confederate troops with exploding ordinances resulting in the defenders burrowing into the loess (e.g., gopher holes) to seek protection (Fig. 12). In addition, the Confederate troops reinforced and solidified their earthworks, as the Union troops dug theirs. Although many skirmishes occurred during the siege, the second Union assault did not begin until June 13th, 1863. After an hour of artillery bombardment, Gen. Banks requested Gen. Gardner's surrender, as he was outgunned, outmanned, and low on supplies and ammunition. Gen. Gardner declined to surrender and the bombardment continued through the whole day and night. The Union assault began at 3:30 a.m. on June 14th, 1863, with the advance of Gen. Paine's troops. These troops breached the Confederate line near Priest Cap (Fig. 13), but were not able to maintain control. Assaults were also made against the Citadel to the south and Fort Desperate to the north (Fig. 13). By the end of the day, Port Hudson remained firmly under Confederate control, and the Union troops had losses (e.g., killed, wounded, captured or missing) in excess of 1,800 men.

In between the back and forth attacks, the Confederate troops reinforced their positions. The Union engineers advanced their saps (e.g. trenches) toward the fortifications, and began digging mines beneath the earthwork in order to place explosive devices, in an attempt to damage the fortifications (Figs. 14 and 15). Records show that tunnels up to seventy feet into the ground were dug by the Union soldiers without shoring (i.e., ceiling support). All this digging and piling of earth is evidence of the engineering properties of the loess. The loess allows for relatively easy digging, while remaining cohesive, maintaining stable steep slope, and draining relatively well. These saps can be seen in the vicinity of Priest Cap, Fort Desperate and the Citadel (Figs. 12, 14 and 15). A third assault was planned by Gen. Banks for July 7th, 1863. However poor weather conditions delayed the operation. The confederate forces at Vicksburg (the Gibraltar of the Confederacy) surrendered to Union Gen. Grant's troops on July 4th, 1863. Upon learning of the surrender, Gen. Gardner contacted Gen. Banks, to negotiate the surrender of Port Hudson (July 8th, 1863). At 7:00 am on July 9th, 1863, the Union forces entered the Confederate fortification through the Jackson Road sally port (south of Priest Cap), and took over the position. The siege of Port Hudson, the longest of U.S. military history (48 days), had ended. On July 14th, 1863 the new Port Hudson Freemen (vol. 1 no. 1) reported that "The Rebel Sebastopol has fallen!!" Over this time period nearly 50,000 men were

Figure 10: Mississippi River meander at Port Hudson (Map of Port Hudson and its defenses by Capt. Fremaux, Gilmer Map Number 409, OP-276/264, in the Jeremy Francis Gilmer Papers #276, Southern Historical Collection, Louis Round Wilson Special Collections Library, University of North Carolina at Chapel Hill, reproduced with permission).



A Descriptive List of River Batteries.

Designation of Batteries	Number of Guns	Calibre, expressed in lbs	Rifled	Smooth Bore	How mounted	Elevation in feet above low water	River Bank East of Van Winkles	Near Sand Point	Mouth of Thompson's Creek	Broken Levee	Ferry Landing, West Side	Wares' water's edge at low water	Crest of River Bank, direction Ware's	Water's edge, direction of Robertson's	Water's edge, direction of Egan's
							Distant objects, in Yards.								
No. 1	Now Vacant					85	4246	3960	1771	1716	1584	2662	2265	4169	5276
No. 2	1	24	1		Siege carriage		4300	4048	1914	1573	1309	1587	2112	3267	4850
	1	24	1		Barbette										
	1	32	1		Barbette										
No. 3.	1	32	1		Barbette	36.3	4246	4070	1936	1463	1947	1346	1980	3087	4620
	1	42		1	Barbette	41.8									
No. 4	1	64		1.	Columbiad	85.	4147	4081	1947	1375	886	1012	1540	2750	4158
	1	128		1	Columbiad										
No. 5	1	128		1	Columbiad	85	4170	4092	2112	1397	836	1155	1650	2662	4092
No. 6	1	42		1	Barbette	85	4170	"	"	"	"	"	"	"	"
No. 7	1	32		1	Barbette	85	4170	"	"	"	"	"	"	"	"
No. 8	2	24	2		Barbette	57.5	–	4048	1310	1529	965	561	858	2090	2758
No. 9	2	24	2		Siege carriage	40.4	–	–	2242	1573	1444	649	726	1661	2915
	1	24		1	"										
No. 10	1	24		1	"	31.9	–	4070	2610	1770	1320	660	792	1540	1985
	1	32		1	Barbette										
	1	64		1	"										
No. 11	Not occupied.					46.8									
No. 12	1	12	1		Parrott Siege Gun.										
No. 13	Now Vacant					45.8					1760	1781		1122	2090
	19		9	10											

involved in the operation (Table 2), of which more than 9,000 were either killed, wounded or became sick from disease, poor nutrition or the heat. At the Port Hudson National Cemetery (Fig. 2) rest nearly 3,400 unknown and 600 known Unions soldier that died during the battle. Confederate soldiers were buried where they died or in an unmarked cemetery located northwest of the old Town of Port Hudson (Fig. 4).

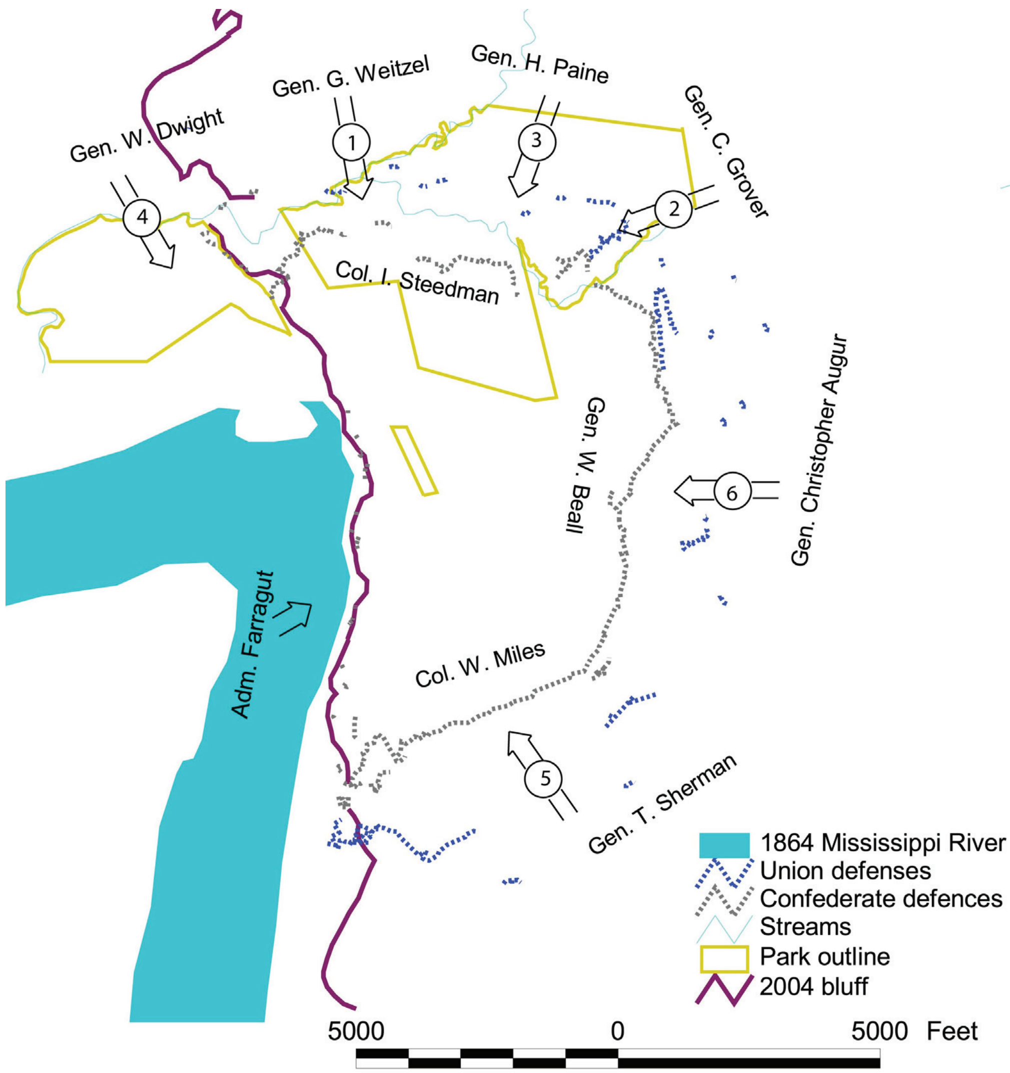


Figure 11: Principal sequence of the May 27th, 1863 Union assault on the Port Hudson fortifications.

Table 2: Estimated Number of Troops Involved

	Confederate Forces	Union Forces	
		Total	Corps d'Afrique
Total Troops	~6,000-6,800	~30,000-40,000	~1,080*
Wounded	~300-482	~2,945-3,454	~95-155
Sick	?	~4,000	?
Killed (combat)	~176-200	~496-752	~34-37
Killed (diseases)	~200	?	?
Missing	?	~319-418	~116
Taken prisoner	~5,500	?	?

*Note: * only includes soldiers from the 1st and 3rd Louisiana Native Guard.*

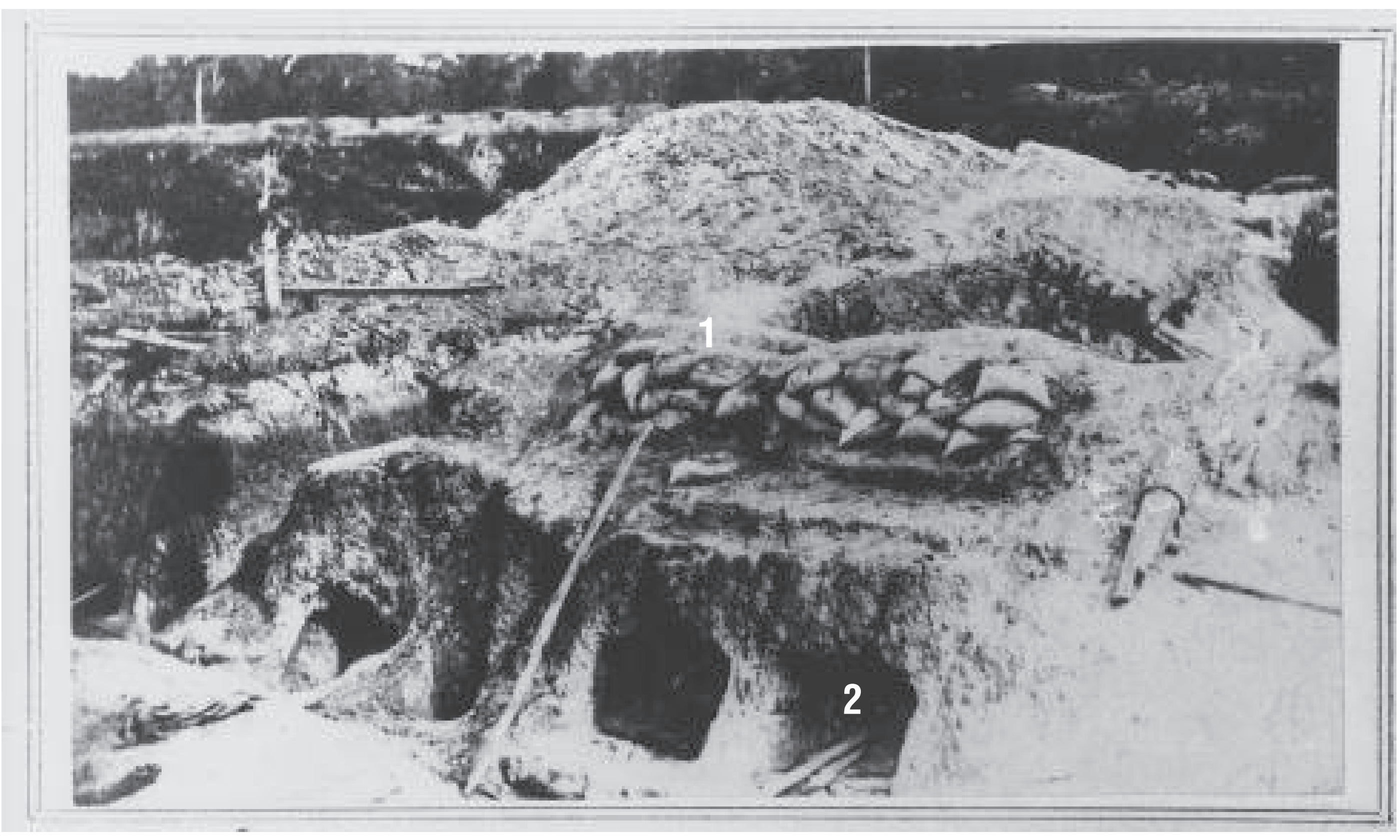


Figure 12: Rifle pits outside the Citadel; (1) is the top of the rampart and (2) a bombproof gopher hole (Louisiana Historical Photographs Collection of the State Library of Louisiana; reproduced with permission).

Post American Civil War

Following the American Civil War, the fortifications at Port Hudson were occupied by the U.S. Army, which maintained there a garrison and a recruitment center for African-American troops. The site was abandoned by the U.S. Army in 1866. By 1872, the railroad was in disrepair and very little of the town remained. In 1876, what remained of the landing was moved to Port Hickey and the railroad extended to the new landing. The railroad was abandoned in 1889 and the landing at Port Hickey in 1908. It appears that the two decades after the end of the battle were a time of high erosion in the study area. All the earthwork construction, the deforestation to build abatis and the bombardment appear to have accelerated the formation of gullies and the rapid expansion of stream network entrenchment, as well as bluff erosion (Fig. 16).

Port Hudson felt into relative obscurity until the mid 1950's when local efforts were started to conserve the battlefield for future generations. In 1965, the State of Louisiana purchased the 640 acres located on the north side of the battlefield (Fig. 3). In 1968, a kraft pulp mill was built by Riegel Paper Company south of Port Hudson, on what was the southern tip of the battlefield near the Citadel and Devil's Elbow, an area formerly known as the Fontania and Hickey Plantations (Fig. 5). In 1969, Georgia-Pacific LLC acquired the mill and converted the facility to pulp and paper. During the late 1970's, oil and gas resources were discovered by the AMOCO Production Company in the area. In December, 1973, 8,600 acres surrounding Port Hudson was nominated to the National Register of Historic Places. On May 30, 1974, the Port Hudson battlefield was designated by the U.S. Department of the Interior as a "National Historic Landmark." Finally in 1982, 25 years after the Committee for the Preservation of the Port Hudson Battlefield was formed to preserve the site, the State of Louisiana opened to the public the Port Hudson State Historic Site and National Historic Landmark.

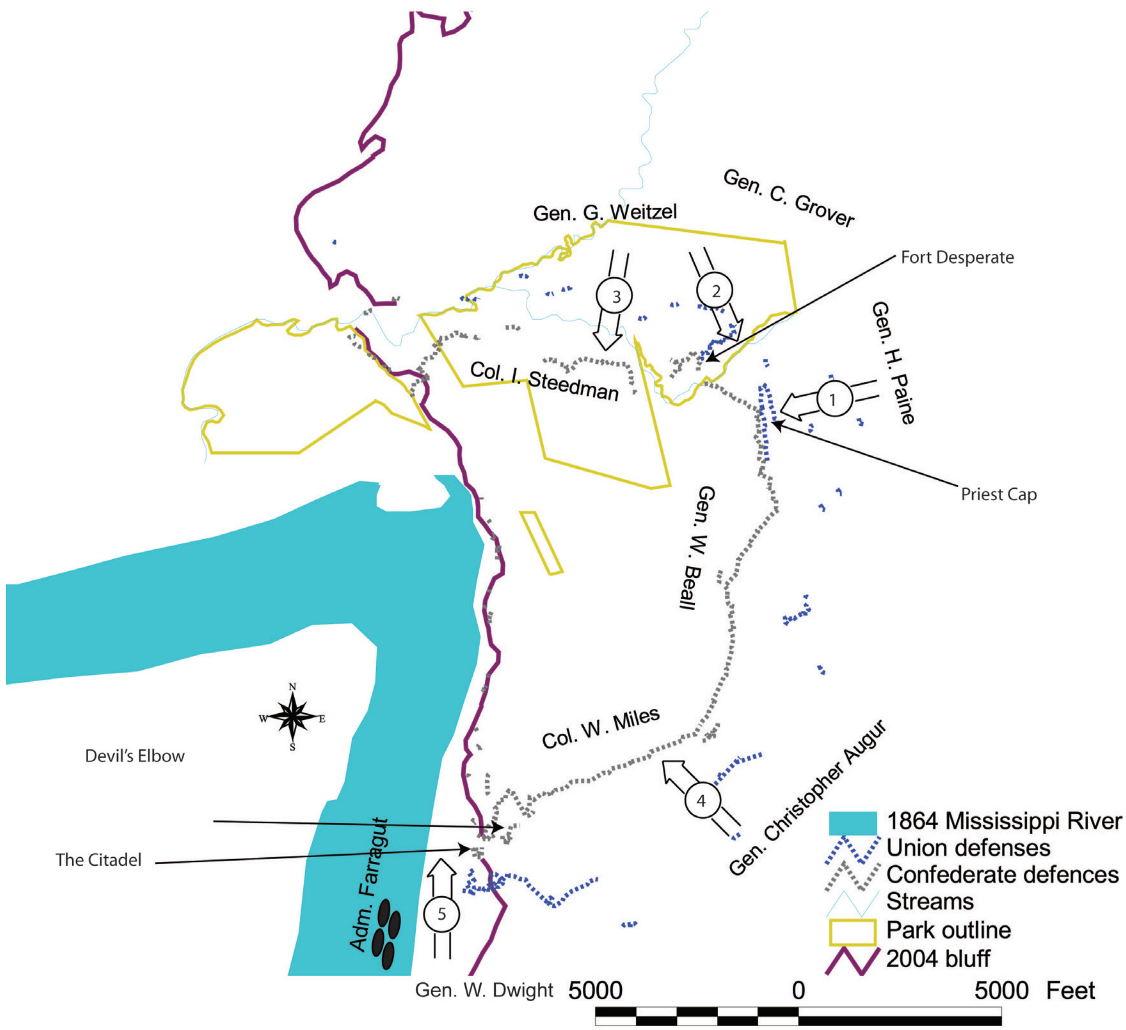


Figure 13: Principal sequence of the June 14th, 1863 Union assault on the Port Hudson fortifications.

Figure 14: Trenches and saps near the Citadel (Louisiana Historical Photographs Collection of the State Library of Louisiana; reproduced with permission).

Figure 15: Entrance to the Union mine under the Citadel (John Langdon Ward Lantern Slides, Mss. 4875, Louisiana and Lower Mississippi Valley Collections, LSU Libraries, Baton Rouge, Louisiana; reproduced with permission).

Figure 16: Photographs taken around 1919 showing bluff erosion and limited vegetation in the vicinity of Port Hudson (Florida Parishes Photographic Collection, Mss. 2355, Louisiana and Lower Mississippi Valley Collections, LSU Libraries, Baton Rouge, Louisiana; reproduced with permission).

A. Rill formation near the top of the bluff

B. Rill formation near the top of the bluff

D. Base of the bluff with a vegetated talus

E. Base of the bluff showing a barren talus (i.e., loo

C. *Base of the bluff showing a sheer cliff*

se material at the base of a slope)

F. *Ferry bluff*

Figure 17: Photograph (looking up river) of the last remaining bluff bordering the Mississippi at Mount Pleasant (photograph taken by the author on 1/13/09).

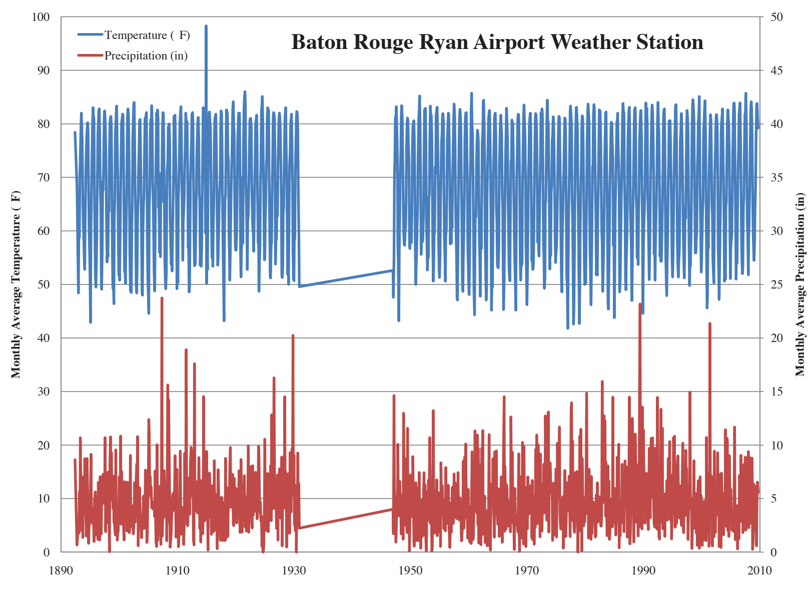


Figure 18: Monthly average temperature (blue) and precipitation (red) at Ryan Airport in Baton Rouge (Source of data: NCDC, 2010).

Natural Regions

The Park and surrounding areas are characterized by a forested upland and marshy, wetland-dominated lowland along the Mississippi River (Fig. 17).

Climate

The study area is located in a hot, humid, subtropical climate with an annual average temperature of ~67°F (19°C), and an average (July) maximum of ~ 91°F (33°C) and (January) minimum of ~39°F (4°C). The area receives an average annual precipitation of ~ 62 in. Precipitation is distributed relatively evenly throughout the year. The area has a 260-day long growing season with a fall first freeze date of November 20th, and a spring last freeze of March 7th. Both the temperature and to a lesser extent the precipitation have remained relatively constant for the last ~120 years, according to the weather station at Baton Rouge's Ryan Airport (Fig. 18).

Physiography/Ecoregions

Within the study area, the uplands east of the bluffs are included in the level IV Baton Rouge Terrace ecoregion of the level III Mississippi River Valley Loess Plains ecoregion. A comprehensive discussion of ecoregions [i.e., geographic areas which exhibits similar ecosystems and environmental resources (e.g., type, quality, and quantity)] is available on the U.S. Environmental Agency website (http://www.epa.gov/wed/pages/ecoregions/la_eco.htm). At the base of the bluff, the lowlands are included in the level IV Southern Holocene Meander Belt ecoregion of the level III Mississippi Alluvial Plain ecoregion. The Baton Rouge Terrace ecoregion is characterized as a deeply-dissected coastal plain, blanketed by Quaternary loess, and covered with hardwood forests. The Southern Holocene Meander Belt ecoregion is characterized as the flat plain and meander-belt of the Mississippi River, and is covered with forested wetlands (e.g. cypress-gum swamp).

The study area lies in the physiographic (i.e., physical geographic) region referred to as the Gulf-Atlantic Coastal Plain. More specifically, the uplands east of the bluff are within the East Gulf Coastal Plain, and the areas at the base of the bluff are within the Mississippi Alluvial Plain. These plains are characterized by a low topographic relief, gentle slope and relatively recent geologic-age surficial deposits. The surficial deposits are mainly of fluvial and aeolian origin, which were influenced by the melting of northern glacier during the last Ice Age. These deposits overlie older marine deposits that were uplifted and are tilted toward the Gulf of Mexico. The upland hardwood forests present on the East Gulf Coastal Plain are considered to be transitional with the Mississippi Alluvial Plain's lowland forested wetland. The forests are characterized as bottomland hardwoods and spruce-pine hardwood flatwood. Directly north of the Park (i.e., West Feliciana Parish), across Thompson Creek, lies the Upper East Gulf Coastal Plain, which differs from the East Gulf Coastal Plain by the presence of loess hills with steep ravines, and the presence of mesophytic (e.g., medium moisture, versus bottomland which have high moisture) hardwood forests.

Topography

Based upon an analysis of light detection and ranging (LIDAR) imagery (Fig. 19) and profiles derived from this data (Fig. 20), it can be seen that the area can be characterized as elevated, approximately 80 feet above river level, flat-land. The land is steeply dissected by streams and exhibits a nearly vertical slope (i.e., cliff) where the ancestral Mississippi River used to undercut its bank (Fig. 7). To the north, the top of the bluff is approximately 67 feet above Thompson Creek. Near Port Hudson, the top of the bluff crests approximately 81 feet above the Mississippi River. The existing bluff at Mount Pleasant rises approximately 72 feet above the river. The elevation above mean sea level of the Mississippi River within its bank is locally approximately 20 feet. The maximum relief in the study area is ~80 feet (24 m). A 3-D rendition of the LIDAR data shows how Sandy and Foster Creeks provided a formidable natural defense for the Confederate fortifications. Profiles A-A' and B-B' (Fig. 20) depict the steepness of the terrain, both at the bluff and along Sandy and Foster Creeks.

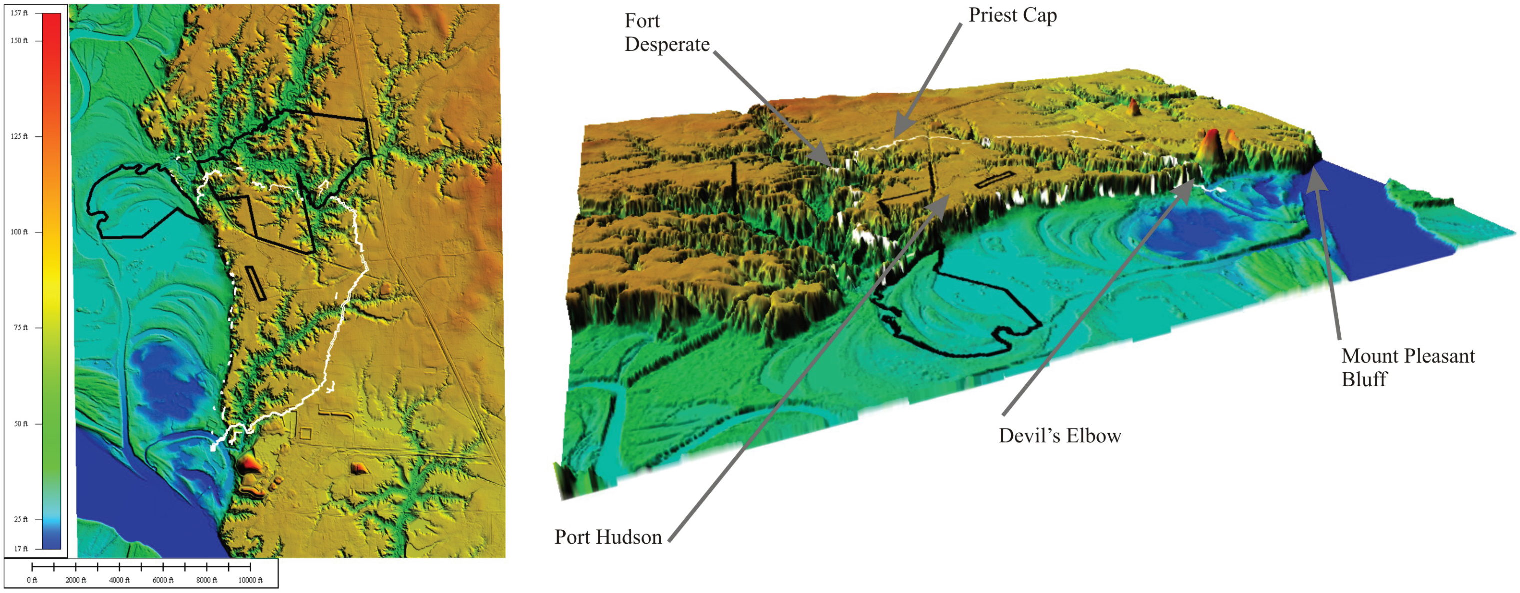
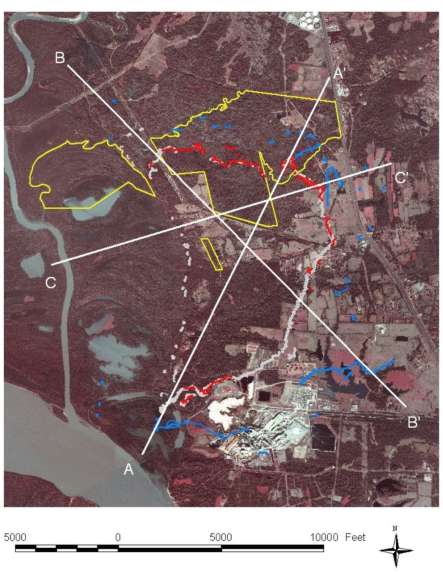


Figure 19: Three-dimensional portrait of the study area. The park boundaries are in black and the Confederate earthworks in white (generated using Global Mapper software).



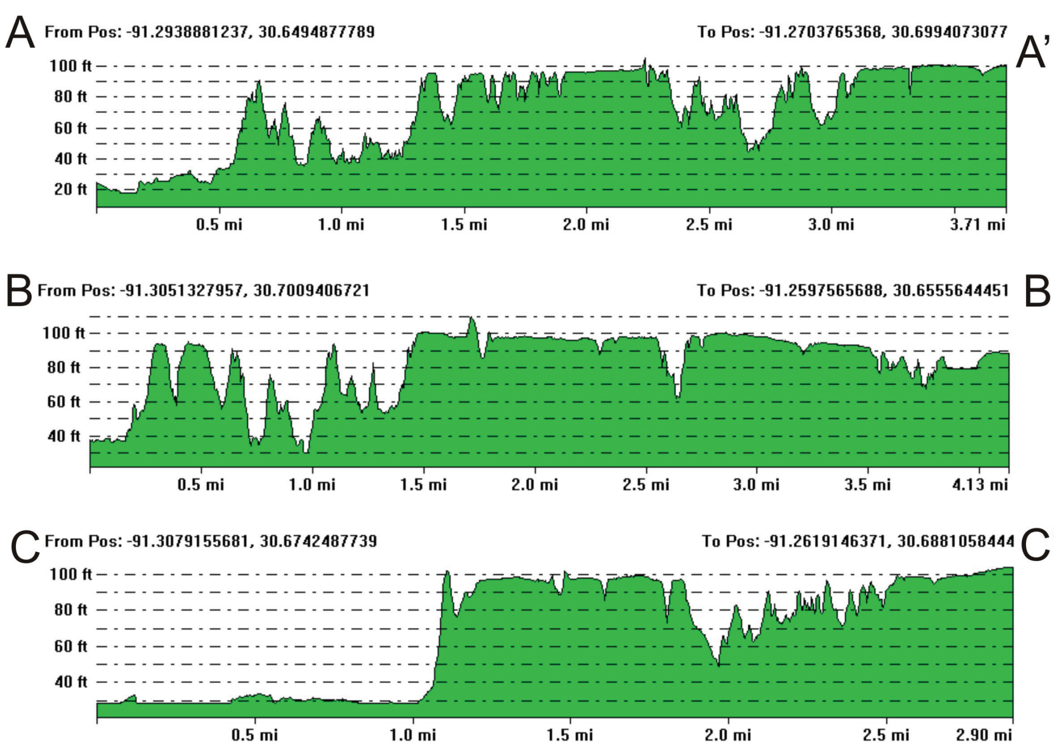


Figure 20: Topographic profiles across the study area (profiles generated using Global Mapper software).

Land Cover/Land Use

The primary land cover of the area is hardwood forest (Fig. 19). However, there are areas north of the West Port Hudson-Plains Road, west of Samuel Road (U.S. 61) and north of the Port Hudson Cemetery Road that are used for crop and grazing land. To the south of the area lies the Georgia-Pacific pulp and paper mill (~1,200 acres). North and northeast of the Park lie other industrial facilities (Fig. 21). The forests are characterized as bottomland hardwoods, and spruce-pine hardwood flatwood; although the northern part of the study area is, as discussed earlier, changing into a mesophytic hardwood forest.

Geology

Port Hudson is located on top of a bluff with both geological and historical significance (Figs. 6, 22 and 23). This bluff or "écor," as it was called by French explorers, is part of the first high ground encountered as travelers navigated up the Mississippi from the bird-foot delta. The word "écor" or "écore" or "accore" (in old French) refers to an elevated sea coast, or an escarpment along a stream caused by water-driven erosion.

Aside from being noticed by travelers, the Mount Pleasant and West Feliciana Mississippi bluffs were the last stop in North America for America's 18th century celebrated naturalist William Bartram (1739-1822). He made mention of the bluff (Fig. 23) and a buried forest located at the base of it in his book, "*Travels through North & South Carolina, Georgia, East & West Florida, the Cherokee country, the extensive territories of the Muscogulges, or Creek confederacy, and the country of the Chactaws; containing an account of the soil and natural productions of those regions, together with observations on the manners of the Indians*" published in 1791. Prof. William Carpenter of Jackson College provided the first detailed geological description of the bluff in a letter to Prof. Silliman at Yale University in December 1838. The letter was published in the American Journal of Science (vol. 35) in 1839. As indicated earlier, the father of modern geology, Sir Charles Lyell (1797-1875) of King's College, London, England, stopped by the bluff in 1846. He described the bluff, and those upriver, in Volume Two of his book collection entitled "*A second visit to North America*" in 1855. In 1869, Prof. Eugene W. Hilgard (1833-1916) of the University of Mississippi used the bluff to describe the type sequence for his Port Hudson Series, which he describes as marsh swamps and estuaries deposits. He described the bluff near Port Hudson as well as near the Fontania Landing (Fig. 8) at low flow, observing the buried cypress stumps at the base of the cut. He indicated that the Port Hudson location was now "inland of an extensive sandbar." Prof. Hilgard associated his top two layers (Fig. 23) as being part of the loess layer. He associated the Port Hudson series as a time of slow subsidence (the "Champlain epoch") and flooding (both Hilgard and Lyell were inclined at the time to believe that loesses were deposited by rivers).

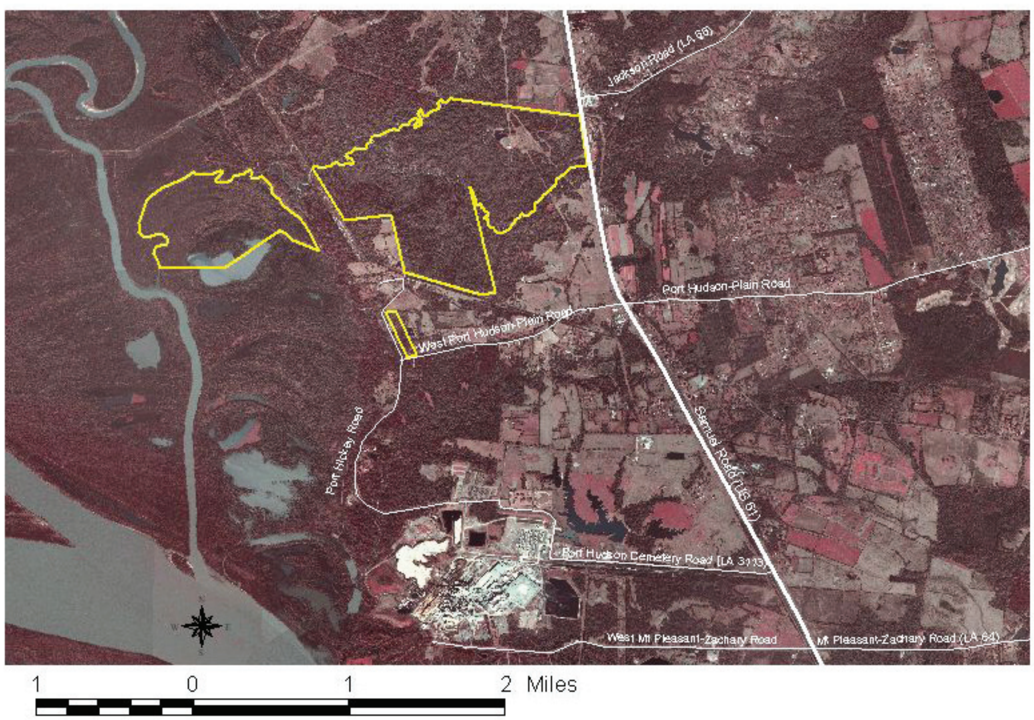


Figure 21: Principal roadways within the study area. The background photograph is the 2004 DOQQ of the Port Hudson area (Atlas, 2008).

Figure 22: Recent photographs of the bluff (photograph taken by the author in 2008-2009).

A. View of the bluff north of Port Hudson along Telegraph Road

B. View of the ruggedness of the terrain along the base of the bluff along Telegraph Road


C. View of the Mt Pleasant bluff from the top


D. View of the Mt Pleasant bluff from the base

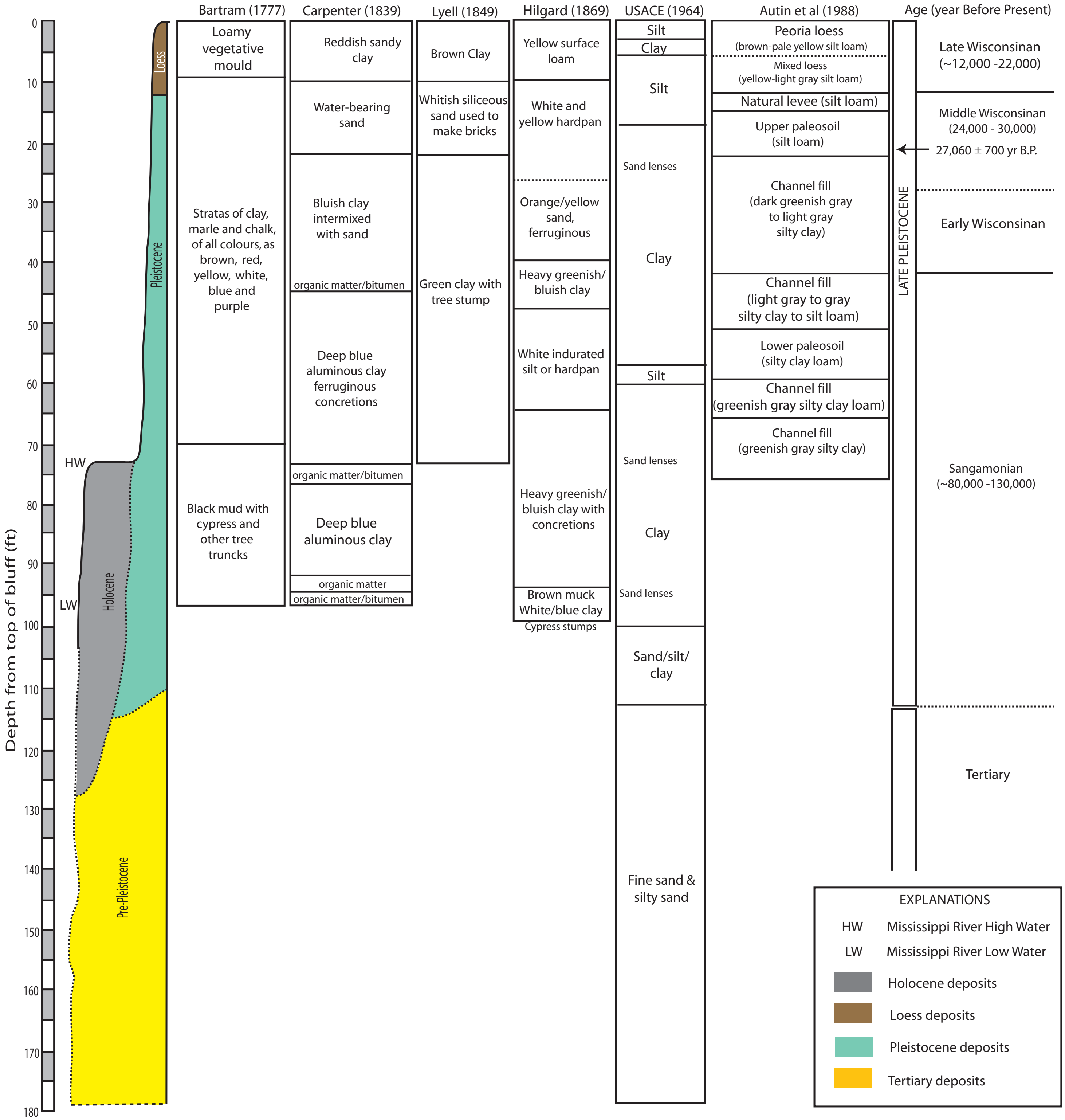


Figure 23: Evolution of the geologic description of the Mount Pleasant bluff over time.

This series was redefined by Prof. Harold N. Fisk (1908-1964) of the Louisiana Geological Survey, in 1938 to the Prairie Terrace. He included a detailed description of the Prairie Terrace in his landmark 1944 publication entitled "*Geological Investigation of the Alluvial Valley of the Lower Mississippi River*". He defined it as a sequence of fluvial deposits which merge into the deltaic plain. Recent studies have formerly modernized and standardized the geology to the characterization presented in this report.

Surface Geology

Surficial Soils

Surface soil data can be obtained from the U.S. Department of Agriculture's Natural Resources Conservation Service (http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx). Excerpts of the local soil map and report are included in Appendix B. Locally, the most common soil type on the top of the bluff is the Feliciana silt (FeB) and silt loam [FeD (3-8% slope) and FeF (8-30% slope)], Scotlandville silt [SnA (0-1% slope) and SnB (1-3% slope)], and Oprairie silt [OpA (0-1% slope) and OpB (1-3% slope)]. The Feliciana silt and silt loam are very well-drained soils and are found predominantly closer to the bluff. The Scotlandville and Oprairie silts are found east of the bluff, and are somewhat poorly- to moderately-well-drained soils. At the base of the bluff, the soil types belong to the Crevasse loamy sand (CR), and Tunica (Tu) and Sharkey (SoB) soils. The Tunica and Sharkey soils are the most dominant, and are composed of clays, which are poorly-drained and frequently flooded. The Crevasse loamy sand, which is found in the vicinity of Port Hickey, represents river terraces that are composed of sand.

Pleistocene Deposits

Beneath the soil horizons, a veneer of loess is present, which correlates to the late Wisconsin Stage Peoria Loess (Fig. 23). The loess mantles the Pleistocene Series and older strata, but not the younger Holocene Series undifferentiated alluvium or other surficial deposits (e.g. fill). Beneath the loess, the battlefield is predominantly underlain by the Hammond alloformation (Pph) deposits (Fig. 24) of the Prairie Allogroup. The Pph deposits are of middle to late Wisconsin (e.g. early Sangamon) Stage, and represent floodplain, meander-belt and backswamp deposits, characterized by fine-grained (e.g. clays) deposits. The Irene alloformation (Ppi) also belongs to the Prairie Allogroup. The Ppi is characterized as middle Pleistocene Series alluvial deposits from the ancestral Mississippi River, or one of its tributaries.

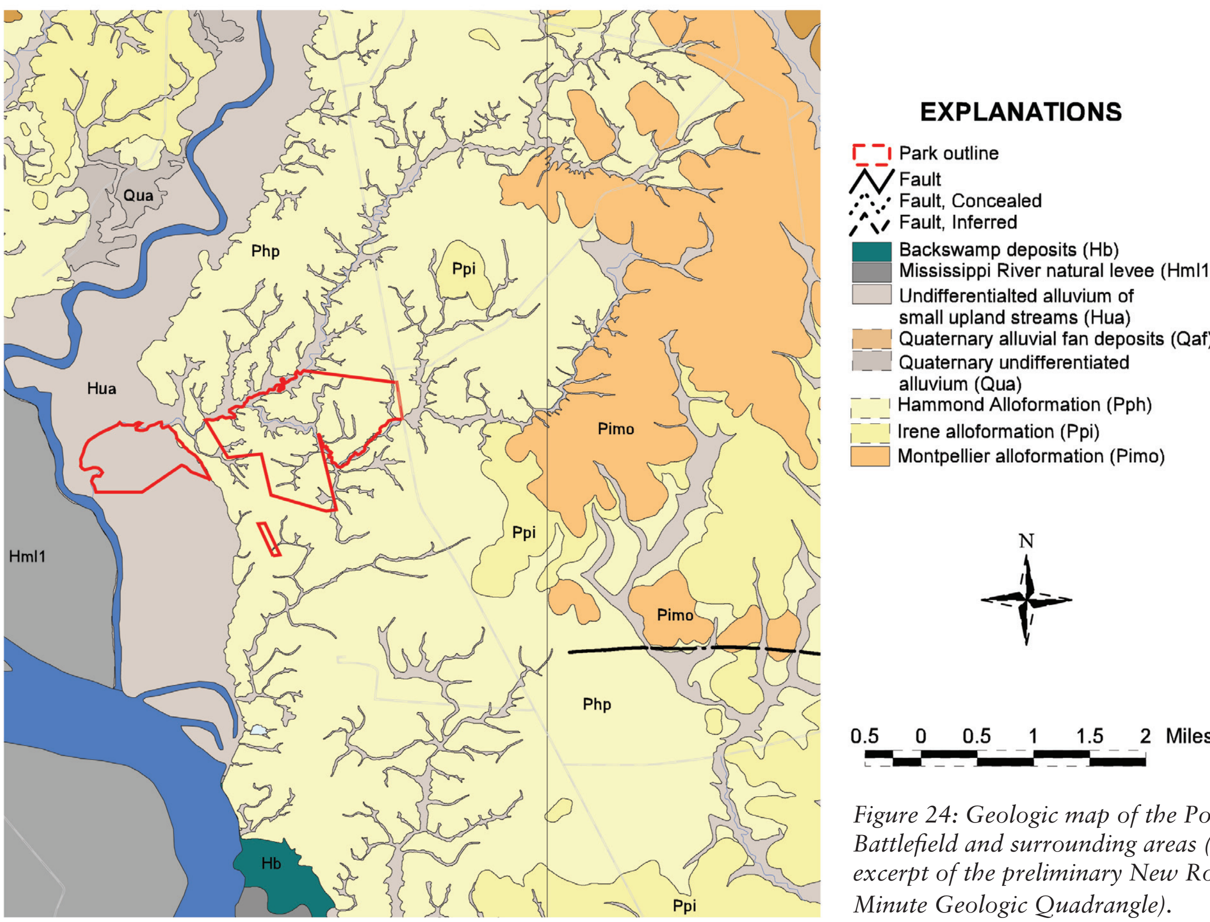


Figure 24: Geologic map of the Port Hudson Battlefield and surrounding areas (source: excerpt of the preliminary New Roads 30x60 Minute Geologic Quadrangle).

Loesses

Loess (also Löß; old German for loose loam) is a fine-grained aeolian (i.e., wind-blown) clastic deposit. It is characterized by its relative homogeneity and limited internal stratification. These clastic (i.e., granular) deposits are predominantly produced by glacial grinding or cold weather weathering. In the case of the loesses at Port Hudson, the source material was weathered during the last glacial period (e.g., Pleistocene Series) impacting the North American Continent.

The Peoria Loess blanketing the study area, as well as areas to the north (Figs. 25 and 26), is a dark to yellowish brown silt deposit characterized by a mixing zone in its lower portion at and near its contact with underlying units [Fig. 20; "mixed loess" of Autin et al (1988)]. Sir Charles Lyell was the first geologist to identify this type of material in the U.S. He did this after describing the Port Hudson and Natchez bluffs. The loess thickness in the vicinity of Port Hudson ranges from 15 to 30 feet thick (Fig. 26). As shown on Figure 23, Prof. Whitney Autin (formerly with the Louisiana Geological Survey, now at the State University of New York at Brockport) and others measured the loess thickness at the Mount Pleasant bluff at ~18 feet.

Some of the physical properties of loesses may explain the ability of the Confederate defenses to sustain the Union's bombardment. Loesses are granular (i.e. formed of elongated spherical grain) in nature, yet contain sufficient soil moisture, clays, organic activity (e.g., plant roots) and calcium carbonate to make the deposits cohesive enough to maintain steep slopes. Cohesion of the loesses has been associated with the presence of clays in the granular matrix. The cohesion is created by the elongated shape of the silt grains and the presence of clays in the form of coating or as interstitial colloids, which generate great inter-particle attraction (e.g., van der Waals forces). Furthermore, surface/capillary tension and hydraulic pressure (e.g., water moisture) in association with the presence of clays in the matrix of loesses also give these deposits some additional cohesion, up to a moisture content threshold. Excessive wetting (greater than ~20% moisture content) and loading of the loess can cause slope failure, and, in some cases, liquefaction. A digital microscope picture of the loess near the Port Hickey Landing is presented in Figure 27.

Particles in loesses are well-sorted and lack stratification, resulting in a relatively uniform texture and therefore uniform properties. Silt particles are tiny grains (e.g. texture similar to natural chalk, but made of small, predominantly siliceous grains), which range in size from 3.9 to 62.5 micrometers (0.00015-0.0025 in) based upon the Udden-Wentworth Scale (i.e., the individual grains are difficult to be seen without magnification). Because this is a granular material, it has porosity (e.g. it is porous), and is therefore permeable (e.g., this material drains relatively well). The total porosity of loesses ranges between 35 and 50%, while the effective porosity (interconnected porosity) ranges between 30 and 35%. Loess permeability ranges between ~0.002 and 100 gal/day/ft^2 (~0.0001 and ~5 Darcy). The wide range of permeabilities observed is the result of the variable nature of grain size distribution, clay and organic content, and cementation in loesses. This range in permeability does not take in account the common presence of macropores or preferential pathways (secondary permeability). It should be noted that drainage through the loess has been associated with preferential pathways or piping systems [e.g., root holes, burrows, joints (e.g., cracks), etc. - Fig. 28], which is also associated with internal erosion and is primarily in a vertical direction. These internal erosional pathways created by pipe flow occurring during storm and normal seepage events create weakness planes or sapping (e.g., slope undercutting caused by groundwater flow) along which loess bluff collapse and ephemeral gully erosion occurs (Figs. 16 and 22). This type of erosion is very common in loess areas where steep hydraulic gradient exist (e.g., steeply inclined groundwater piezometric surface or water table), such as along bluffs.

The geological engineering literature refers to loesses as problem soils for foundations, because of their behavior under variable saturation conditions. Because of loesses' collapsibility and liquefaction issues, differential settlement of structures can occur. The erosion and cliff retreat observed in loesses, where stream/river action is not present, is generally associated with hydroconsolidation [collapse of the loess cohesion due to excessive wetting

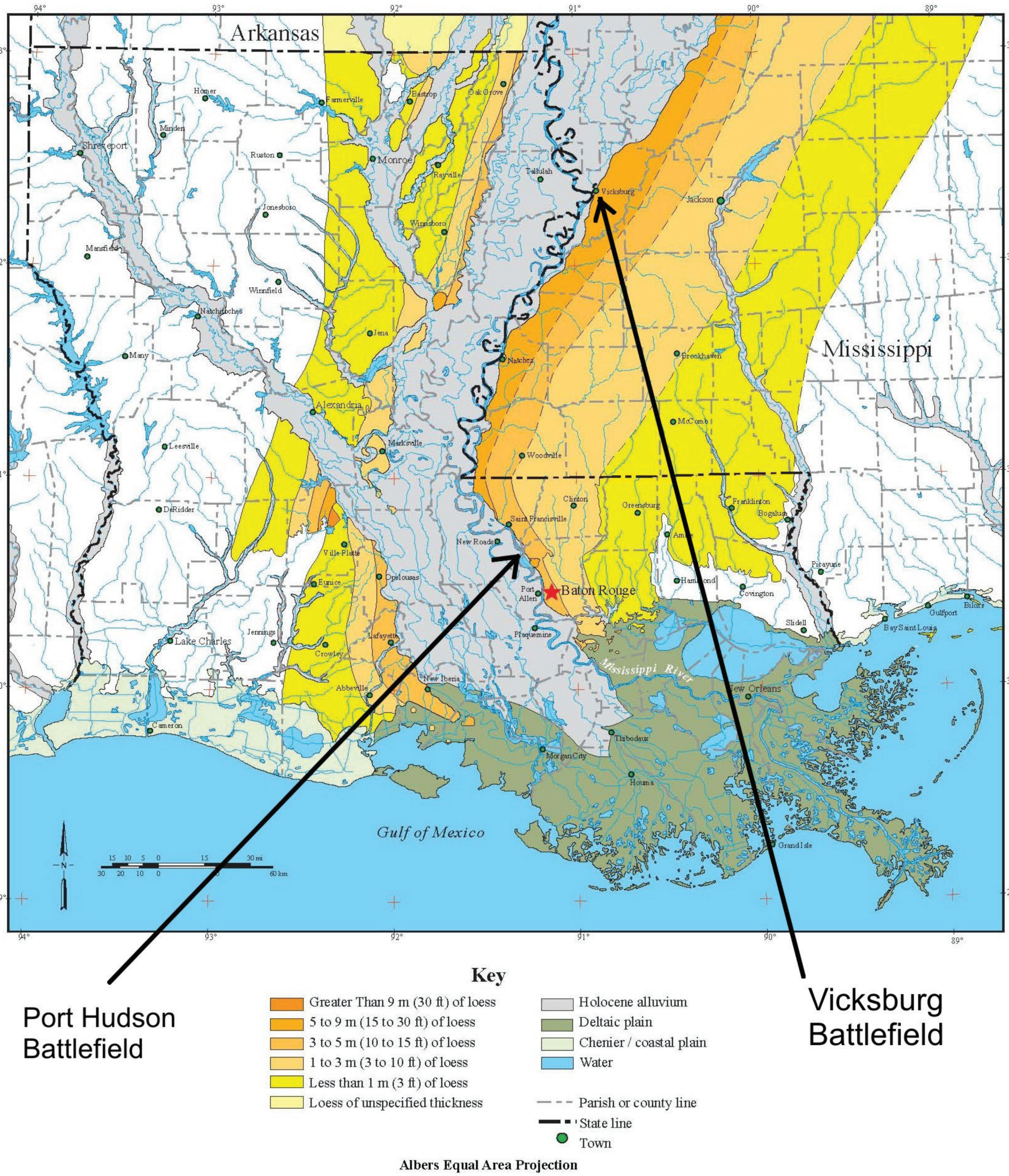


Figure 25: Loess map of Louisiana (source: Heinrich, 2008, reproduced with permission of the Louisiana Geological Survey).

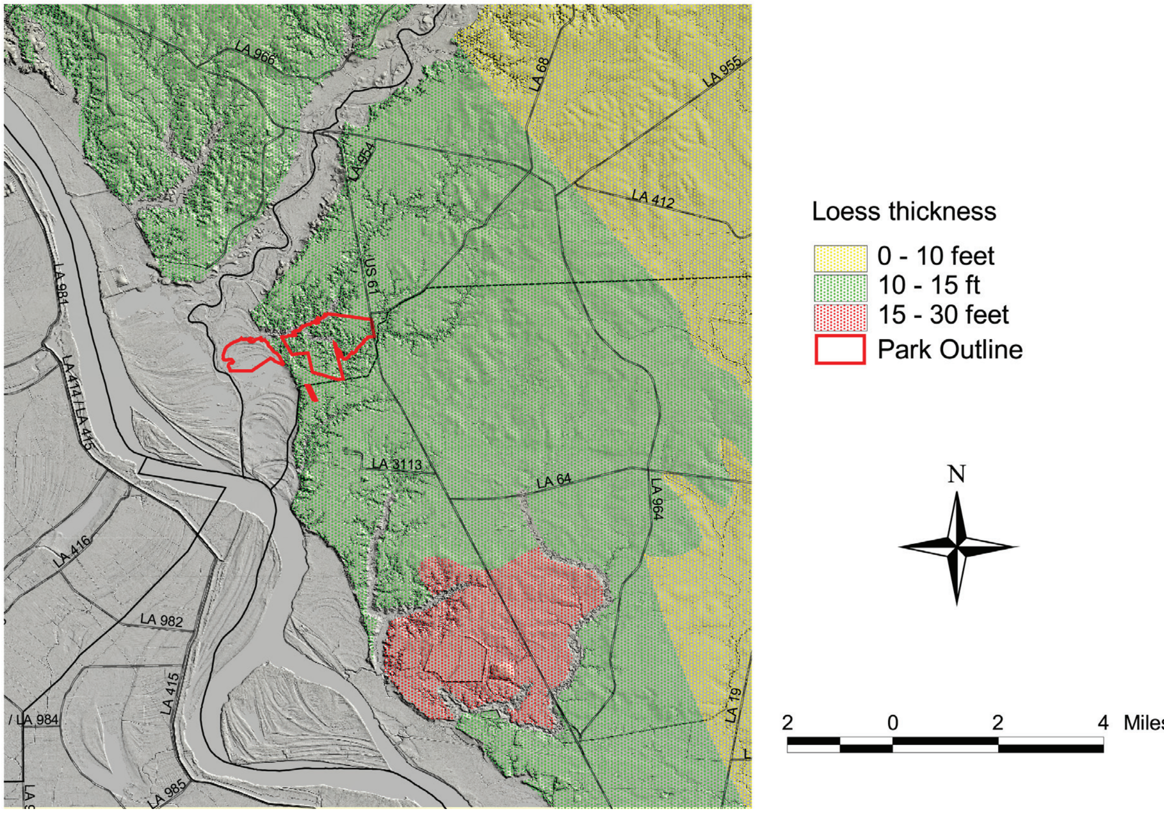


Figure 26: Local loess thickness (modified from Miller, 1983 and McCulloh, undated).

and the resulting loading (caused by the wetting)]. This collapse can be seen in modern (Fig. 22) and older (Fig. 16 and Appendix C) photographs of the bluff, which shows vertical cliffs with talus slope at the base, as well as severe gullying. The talus represents the residual material from the collapse of the bluff. At the Mount Pleasant bluff, the bluff erosion is the result from a combination of hydroconsolidation and under-cutting by the Mississippi River. The observed severe gullying is most likely the result of deforestation for agricultural purposes prior to the Civil War, and from the destruction caused by the siege during the Civil War.

The Peoria Loess at the Mount Pleasant bluff is composed of ~76% silt and ~19% clay size particles (the remained fraction is fine sand). Similarly, the mixed loess is composed of ~71% silt and ~22% clay size particles (the remaining fraction is coarser sand grains). Because of the presence of clay particles in significant amounts (~20 percent) the loess is also cohesive, enabling this material to maintain nearly vertical slopes (e.g., the bluff and ravines).

Geotechnical tests performed on the loess at the Georgia-Pacific, LLC property indicate that these deposits exhibit the following properties:

1. a relatively high horizontal hydraulic conductivity [6.6x10-4 ft/sec (2.0x10-3 cm/sec or 2.1 Darcys)], which suggests an ability to drain easily, as exhibited by the Feliciana Silt and Silt loam soils;

2. medium shear stress (e.g., strength or matrix suction) values ranging from 1,000-1,800 lbs/ft^2 [(pounds per square-foot) or 48-86 kPa (kilopascals)], indicating that, although the material will hold under applied weight, it does reach a breaking point where unconfined (e.g., the bluff) and/or will compact; the shear strength is the product of the material's internal friction and cohesion;

3. the very hard consistency (i.e., ability to remain together) of the loess [ranging from 35->40 blows/ft (i.e., 140-lb hammer dropping 30 in. on a 18-in. long and 2-in. in diameter split spoon soil sampler) on a standard penetration test], suggesting that it will hold its shape under pressure, such as bombardment;
4. an intermediate to high cohesion value [>4.0 ksf (kilopounds per square-foot) or >192 kPa] which, similarly to shear strength, indicates that the loess can maintain steep slopes.

It should be noted that loesses have low to moderate plasticity, and therefore have the tendency to progressively lose cohesion when reaching excessive dryness, as well as reaching above the plastic limit (e.g., the moisture content at which a material behaves in a plastic manner), a critical moisture content (greater than ~20%). As moisture content increases (up to ~20%) the cohesion of the loess increases and its internal friction decreases. Beyond the critical moisture content, the internal friction begins to increase and the loess looses cohesion, leading to possible slope failure. When saturation increases above the liquid limit (e.g., moisture content at which a material behaves in a liquid manner), the shear strength or matrix suction of the loess decreases enabling mass movement (e.g., landslide) to occur. These deposits have a low density (<0.05 lb/in^3 or <14 kN/m^3). These types of properties enabled the Confederate earthworks to maintain their integrity and also enabled the Union engineers to dig unsupported mine shafts several hundred feet in length into the ground. This digging was an effort to undermine the Confederate earthworks of the Citadel and Priest Cap. These shafts were excavated without timbering for ceiling supports under constant bombardment and the occasionally inclement Louisiana climate. This type of unsupported excavation can still be seen today in the Loess Plateau region of China where modern cave houses are excavated into bluffs. However, the deforestation, which was the result of the building of the Confederate and Union earthworks and defenses (abatis) and was followed by the siege's bombardment, enabled the exacerbated the gully erosion that followed the battle.

These same properties, that enabled the Confederate defenses at Vicksburg to resist the Union bombardment, allowed the Allied Army to repel the German Army at the Battle of the Somme (northern France) in 1916 (and in a smaller prior engagement in 1914), where the use of mechanized tanks in battle began. Captured documents after the battle showed that the German Army used a geological staff during this battle to prepare and distribute instruction, detailing the proper siting of earthworks. In France's Somme Valley, as at Port Hudson, the hilltops and uplands were formed by silt loam overlying loess (called "limon" in French), which in turn rested over a clay.

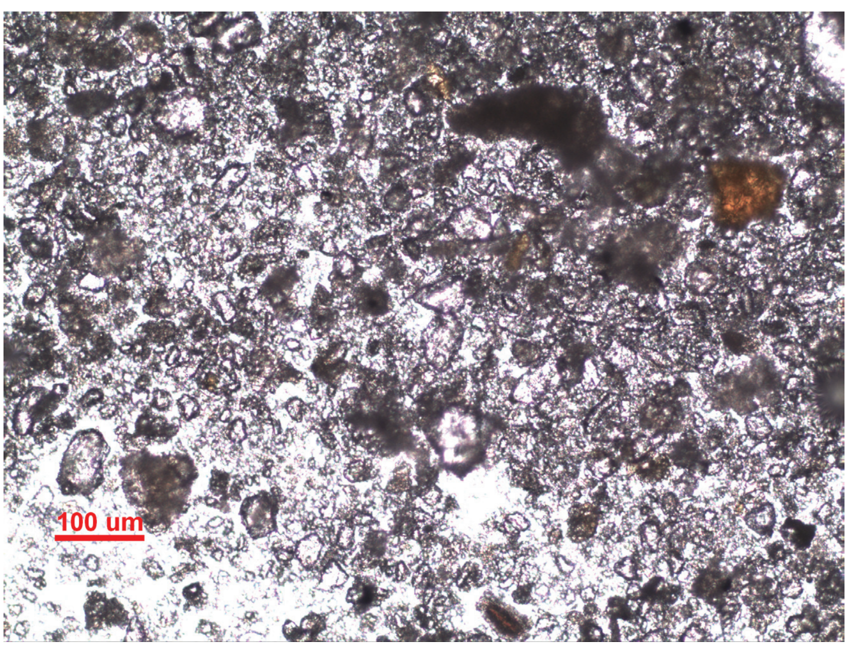


Figure 27: Digital microscope picture of the manually crumbled loess at Port Hudson (collected at Devil's Elbow).

As stated by Douglas W. Johnson in 1921:

"In a war of movement it is the surface forms of the land alone which play a principal rôle in the military operations. But in a war of position, where the opposing armies "dig in" and for long periods remain rooted to a given piece of ground, the character and structure of the soil and rocks beneath the surface exercise a profound influence upon the condition of the armies and nature of the fighting." (Johnson, 1921, p. 105)

He goes on to state that:

"Extensive galleries and tunnels are run for the purpose of sheltering large bodies of troops assembling for an attack, or to place and explode mines under the enemy's trenches. It is evident that the geological formation of some battlefields, consisting of well-drained pervious rocks, may be highly favorable to such military engineering works; whereas in other battlefields, underlain by strata saturated with water which cannot drain off, the construction of tunnels and dugouts and even the digging of deep trenches may be practically impossible" (Johnson, 1921, p. 117)

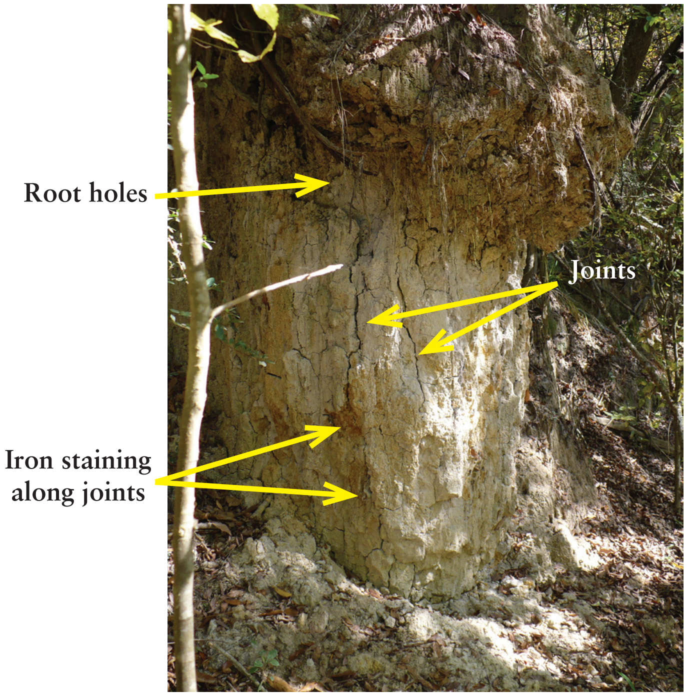


Figure 28: Preferential pathways exhibited by the loesses at Port Hudson.

Shallow faults

Shallow faults are defined herein as subsurface faults that have a surficial expression (i.e. displacement can be seen in the form of a scarp). Port Hudson is located at the northernmost extent of the Baton Rouge-Tepetate Fault System (Fig.29). It is likely that the locations of this set of active to-the-basin growth faults are associated with the presence of a deep-seated Lower Cretaceous reef/shelf margin (Fig. 29). Prof. Ron Zimmerman of the Louisiana Geological Survey related these subsurface faults as a "down to the coast fault zone." He associated this zone with the continuation of the Triassic Period's Wiggins Arch (Mississippi) and the Tertiary Period's Angelina Flexure (Texas - Fig. 30). The Baton Rouge-Tepetate Fault System, which is comprised of listric (a.k.a., shovel-shaped or growth) faults, is the surficial expression of these deeper down to the coast faults. Listric faults are normal faults caused by extensional forces. These extensional forces applied to geologic material pull-apart subsurface rocks/deposits resulting in the downthrown block sliding down the fault plane. These faults are often nearly-vertical features close to the surface (angle >70°). However, as they extend deeper, they progressively become horizontal at depth (angle <45°). The Baton Rouge-Tepetate Fault System is also referred to as an en echelon fault system, as shown on Figure 29. The fault system consists of many faults, which generally slump toward the Gulf of Mexico in a stepwise manner (Fig. 31).

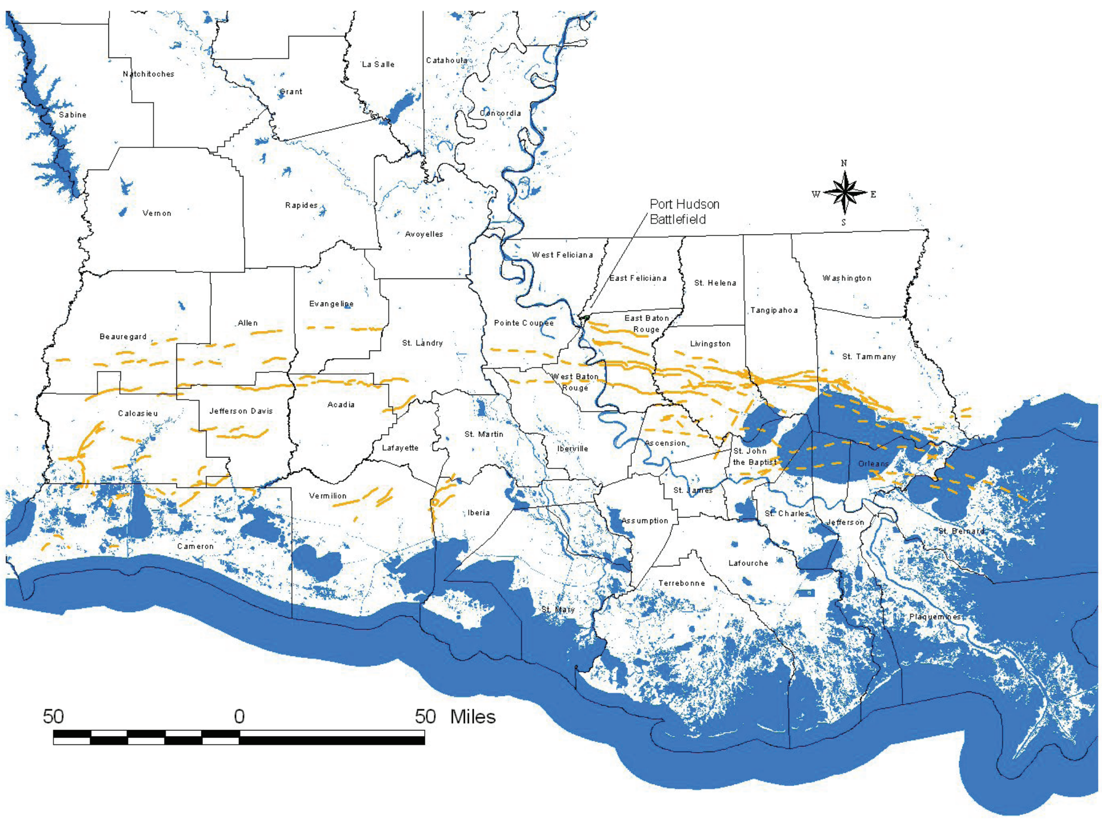


Figure 29: Location of known (solid orange lines) and suspected (dashed orange lines) shallow faults in southern Louisiana (source: Van Biersel, 2006; Milner and Fisher, 2009; and Heinrich, 2000).

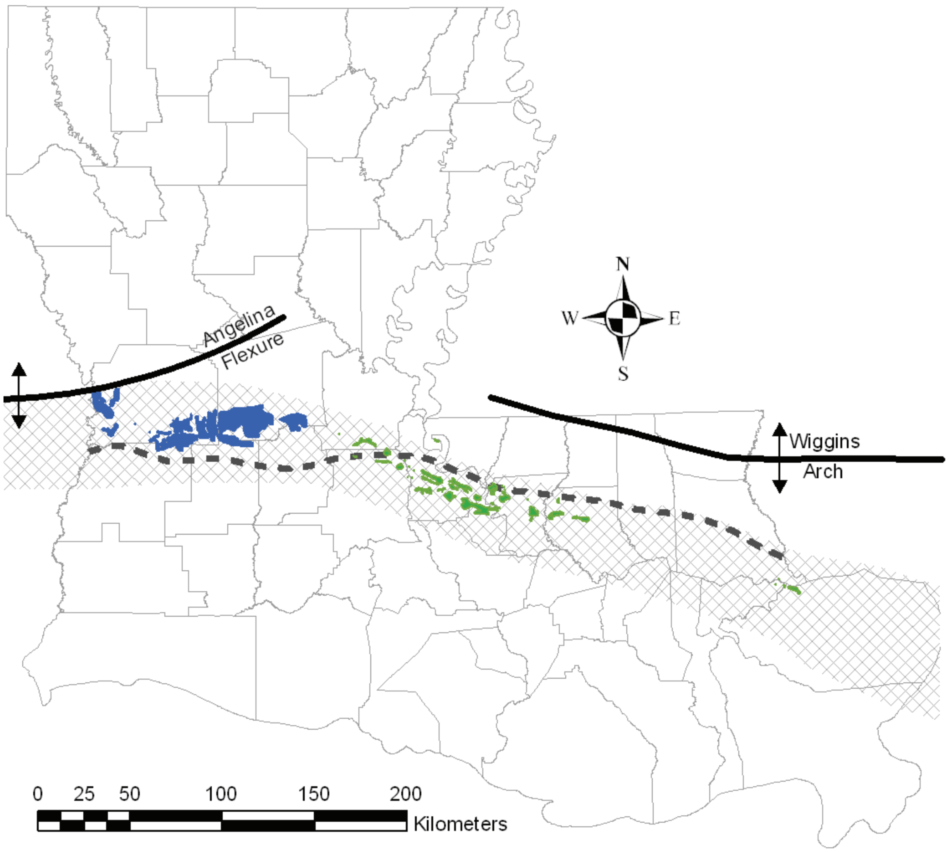


Figure 30: Locations of the Tuscaloosa Trend (cross hatch), lower Cretaceous shelf margin (dashed line), Tuscaloosa Group Play (green) and Austin Chalk Play (blue).

The Baton Rouge-Tepetate Fault System is considered by many researchers as an active fault system. However, there are some exceptions, as follows: (1) the Zachary Fault (located in the vicinity of the battlefield- Fig. 31), and the Alsen Fault to the south, are considered to be inactive; and (2) the Baker Fault, which may be inactive, or is speculative. Mr. Richard McCulloh and Mr. Paul Heinrich of the Louisiana Geological Survey located near the study area an additional, yet unnamed, fault to the northeast of the battlefield (Figs. 24 and33), based upon the presence of displacement at the ground surface. In Baton Rouge, the modern displacement of the Baton Rouge Fault was estimated at ~20 feet, with a cumulative displacement during the Quaternary Period estimated at ~350 feet. It has been speculated that the reactivation of the fault system during modern times may have been caused by sediment loading in the Gulf of Mexico. Other suggested possible causes for reactivation include fluid and energy withdrawal/extraction, such as groundwater, oil and gas.

Stream Patterns

The local streams exhibit a drainage pattern dissimilar to the more common dendritic pattern (i.e., the stream and its tributary are distributed in a manner similar to a tree trunk and its branches). As shown with yellow lines on Figure 32, Sandy Creek and Foster Creek to the north, and Lilly Bayou and Cooper Bayou to the south, exhibit a rectilinear drainage pattern (i.e., the stream and its tributaries have straight segments, as well as repeated branching at specific angles). This type of pattern is not expected on flat-lying sediments. In 1944, Prof. Harold Fisk identified this pattern, and drew regional structural lines that he suggested were trends explaining the drainage patterns within the Mississippi River Valley (red lines on Figs. 32 and 33). More recently, Mr. Richard McCulloh inferred that certain local drainage networks are not dendritic in nature, but show some sort of structural control. He hypothesized that these drainage network patterns may reflect joint distribution.

Although the correlation between geological subsurface structure and Louisiana stream drainage pattern is speculative, the orientation of some, if not most, of Cooper Bayou's and Lilly Bayou's stream segments align relatively well with known or suspected faults (Fig. 31). These faults may be associated with the Port Hudson salt dome (Fig. 34). In comparison, Sandy Creek's and Foster Creek's stream segments orientation is peculiarly parallel, perpendicular and diagonal (Fig. 32) to Harold Fisk's 1944 structural lines (Fig. 33). This observation, although subjective, would indicate that the stream drainage pattern observed for streams located near the Port Hudson salt dome would be affected by this geological structure. In addition, streams near the Park are affected by more regional geological structure and tectonic activity, possibly associated with the basement features. It has been speculated by other authors that the development and widening of joint systems associated with lateral unloading (e.g. erosion of the bluff) and the presence of weaker zones (e.g. more prone to hydroconsolidation) within the loess can foster the development of similar stream networks. This type of retrogressive failure is self-perpetuating as long as the steepness of the bluff remains present. This last hypothesis is consistent with the fact that the rectilinear drainage pattern ca be observed near the bluff, but resume to be dendritic some distance away from the bluff.

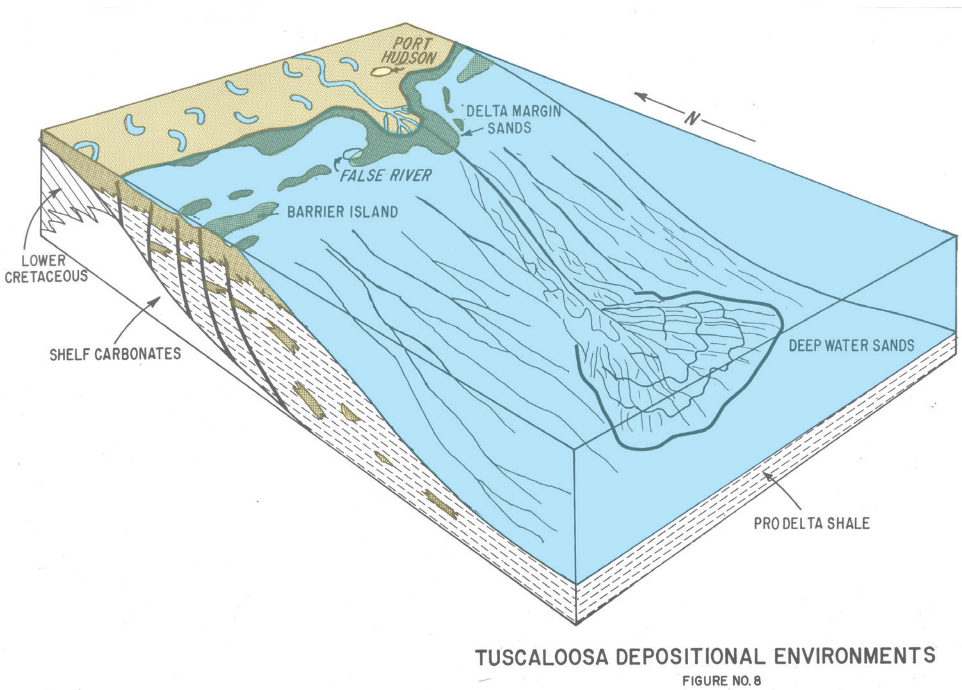


Figure 31: Block diagram depicting the environment of deposition of the Tuscaloosa Trend at Port Hudson (source: Steward, 1981, reproduced with permission from the New Orleans Geological Society).

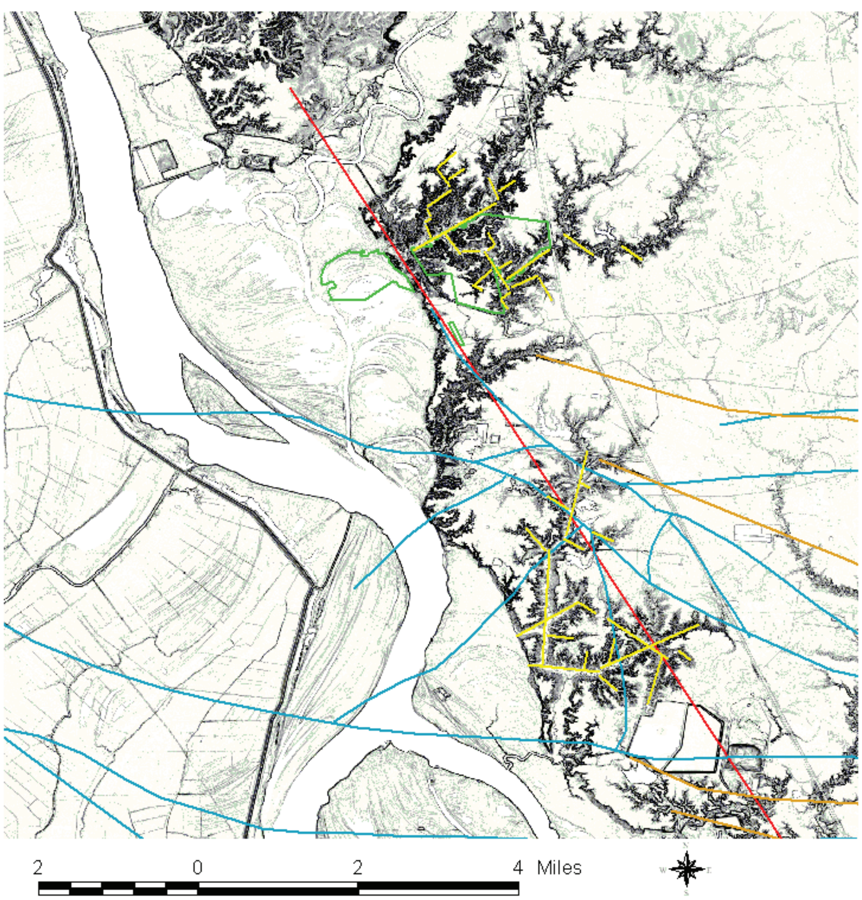


Figure 32: The generalized lineaments discernible in drainage patterns (yellow lines). The faults (orange and blue lines) and Fisk's (1944) postulated structural control lines (red line) within are also shown. The Park is colored in bright green.

Subsurface Geology

The local subsurface geology ranges from modern (Holocene Series) sedimentary deposits to the Paleozoic Era [<248 million year (MY) before present (B.P.)] basement (i.e., the bedrock below the sedimentary deposits). The basement rocks (i.e., continental crust) are most likely composed of igneous (e.g., granite) and metamorphic rocks (e.g., gneiss), and were formed during the break-up of Pangaea during the Permian Period, and the formation of the Ouachita Mountains during the Triassic Period. These basement rocks are blanketed by the Jurassic System Louann Salt (i.e., evaporite geologic formation), which is the source for the southern Louisiana salt domes, such as the Port Hudson and nearby Irene salt domes. These salt domes are important to Louisiana, as they create structural traps where oil and gas can be concentrated. In 1952, Dr. Lewis Nettleton, the father of exploration geophysics, estimated that the Louann Salt lay approximately 25,000 feet below the ground at Port Hudson. Above the Louann Salt lies a series of Cretaceous and Tertiary Period shallow- to deep-marine sedimentary and evaporite formations (Table 3). The formations deposited during the Quaternary Period were deposited predominantly in a freshwater (e.g., non-marine) environment. All formations below the Catahoula Formation contain mostly saltwater and some petroleum products. The Catahoula and younger local deposits contain freshwater, although most of those contain saltwater south of the Baton Rouge-Tepetate Fault System.

The sedimentary layers close to the Wiggins Arch dip steeply toward the Gulf of Mexico. The Wiggins Arch (Fig. 30) is an anticlinal structure (i.e., upward fold) in the basement, formed during the Triassic Period. It represents the northernmost limit of the Louisiana Salt Basin (where the Louann Salt is found) and the southernmost limit of the Mississippi salt Basin to the north. The structures represent a ~5,000-foot uplift of basement rocks

For simplicity, in this report only the geological formations of geological or economical significance to the area surrounding Port Hudson will be discussed in detail. Other units, such as the Jackson Group and Cook Mountain Formation and others, which are petroleum producers in other parts of the state, will not be discussed, since they are not of specific interest for this locality. The Pliocene and Miocene Series' Southern Hills Aquifer System is discussed in the Geohydrology section of this document in connection with groundwater resources.

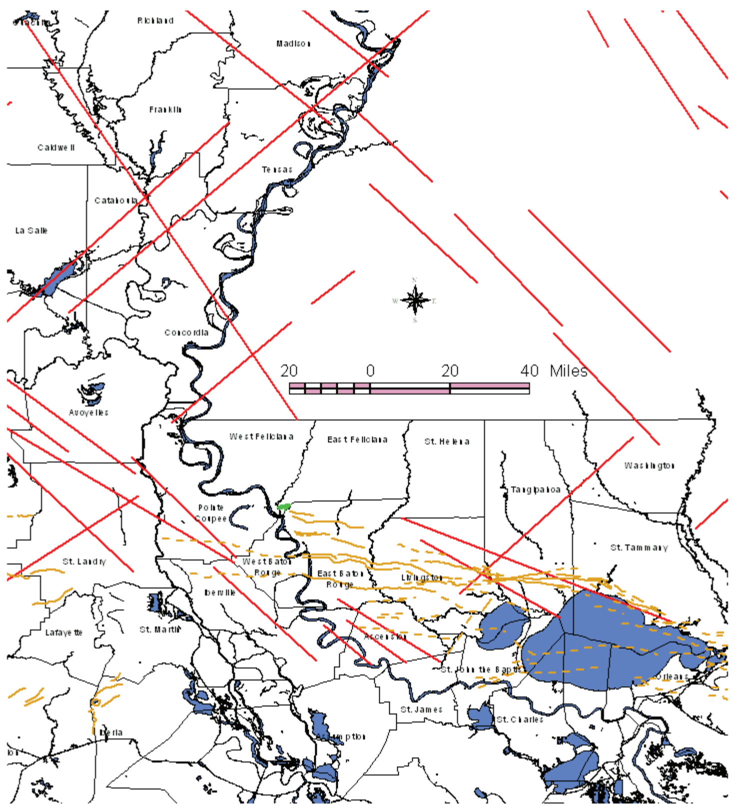


Figure 33: Location of known (solid orange lines) and suspected (dashed orange lines) shallow faults in southeastern Louisiana with Fisk's (1944) postulated structural control lines within the Mississippi River alluvial valley. The Park is colored in bright green.

Mississippi River Valley Alluvium

From the top of the bluff at Mount Pleasant, the U.S. Army Corps of Engineers (USACE) has estimated that the base of the channel of the Mississippi River is ~180 feet deep, and the base of the valley sediments is approximately ~300 feet deep (Fig. 35). The USACE boring that was drilled at the top of the Mount Pleasant Bluff identified the base of the Pleistocene and top of the Tertiary System deposits. The Mississippi River alluvium is composed of interbedded and discontinuous layers of granular (sands and gravels) channel fill and crevasse splay, and fine-grained (silts and clays) overbank deposits. Large amounts of organic material are also included with the fine-grained overbank deposits, which are associated with the occurrence of swamps and wetlands on the floodplain.

Wilcox Group

The Wilcox Group was deposited in a shallow-marine deltaic environment. It is composed of discontinuous layers of alternating sand and clay. As a geologic formation, it is of importance in Louisiana, as it is a source of natural gas and oil throughout much of the state. In addition, it is a source of coal and groundwater in the northwestern portion of the state. The Wilcox produces oil and gas above the Port Hudson salt dome, as well as at the nearby Irene salt dome. Near Port Hudson, the Wilcox group is approximately 3,000 feet thick and is found at a depth of ~9,500 feet below the ground surface.

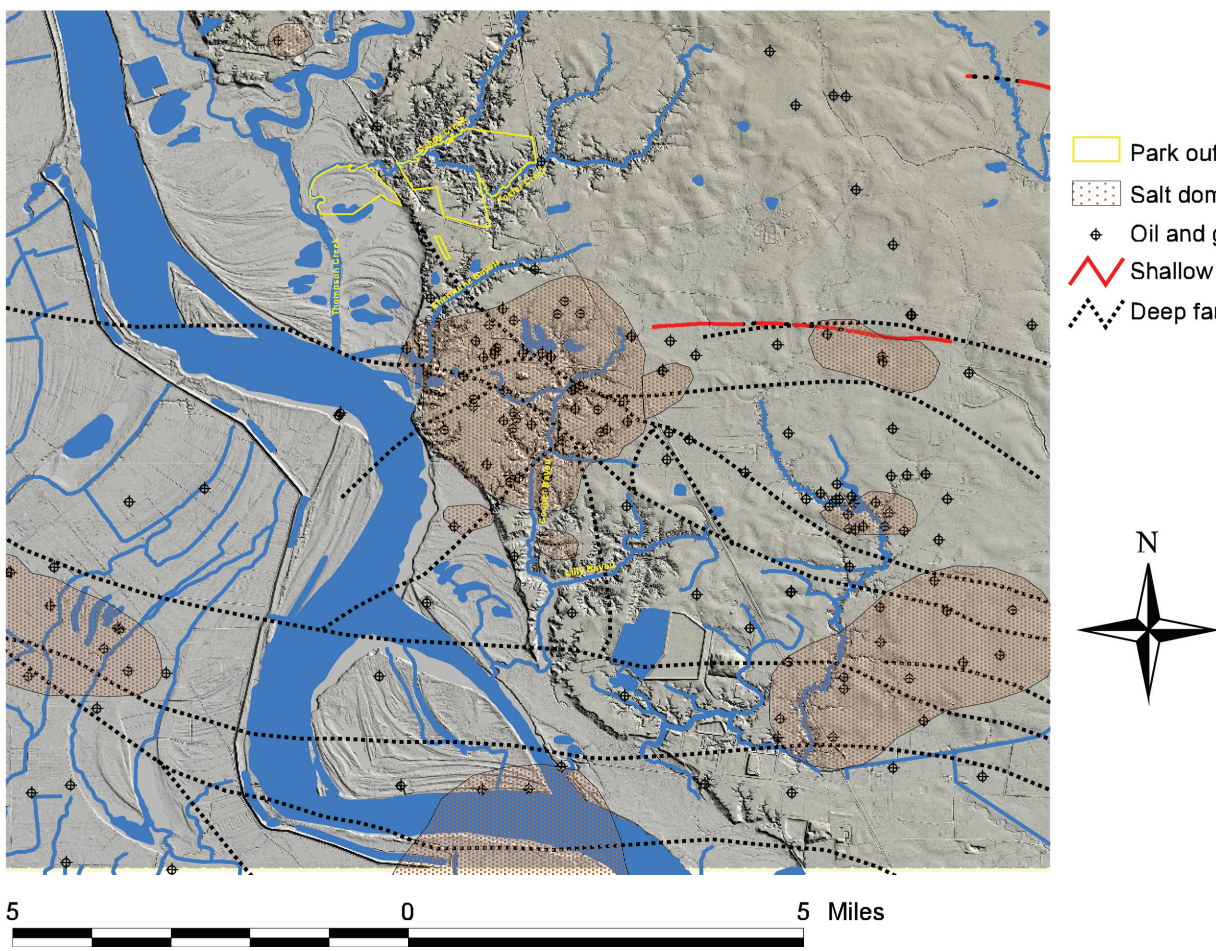


Figure 34: Locations of deep seated faults associated with the Port Hudson oil and gas field (Source: Van Biersel, 2006 and GeoMap Co., 2002).

Table 3: Generalized Stratigraphic Column of the Port Hudson Area

Erathem /Era	System/ Period	Epoch/ Series	Group	Formation/ Member	Aquifer		Depth (ft)	Age (MY BP)
Cenozoic	Quaternary	Holocene		Recent Alluvium	Alluvium	Mississippi River Alluvium		
		Pleistocene	Prairie Allogroup					
			Intermediate Allogroup					
			Upland Allogroup					~1.8
	Tertiary	Pliocene			400-foot Sand	Southern Hills Aquifer System		
			Fleming*	Blounts Creek	600, 800, 1000, 1200, 1500, 1700, 2000, 2400, 2800-foot Sands			
		Miocene		Castor Creek				~5.3
				Williamson Creek				
				Dough Hills				
				Carnahan Bayou				
				Lena			~2400	~23.8
			Catahoula*	Anahuac	Catahoula	Catahoula		
		Oligocene		Frio			~8000	~33.7
			Vicksburg	Rosefield	No freshwater			
				Sandel				
		Eocene	Jackson	Mosley Hill				
				Danville Landing				
				Yazoo Clay				
				Moodys Branch				
			Claiborne	Cockfield				
				Cook Mountain				
				Sparta				
				Cane River				
				Carrizo				~54.8
		Paleocene	Wilcox	Sabinetown			~9000	
				Pendleton				
				Marthaville				
				Hall Summit				
				Lime Hill				
				Converse				
				Cow Bayou				
				Dolet Hills				
				Naborton				
			Midway	Porters Creek				
				Kincaid				~65.0
Mesozoic	Cretaceous	Gulf	Navarro	Arkadelphia			~14000	
				Nacatoch				
				Saratoga				
			Taylor	Marlbrook				
				Annona				
				Ozan				
			Austin	Brownstown				
				Tokio				
				Rapides				
			Tuscaloosa	Eagle Ford			~17,000	
				Pepper Shale				

Modified from: Johnston et al, 2000 and Van Biersel et al, 2009.
Note: the table only shows unit overlying the Tuscaloosa Group
** indicates that the formation or set of formations is not formally recognized as a Group.*

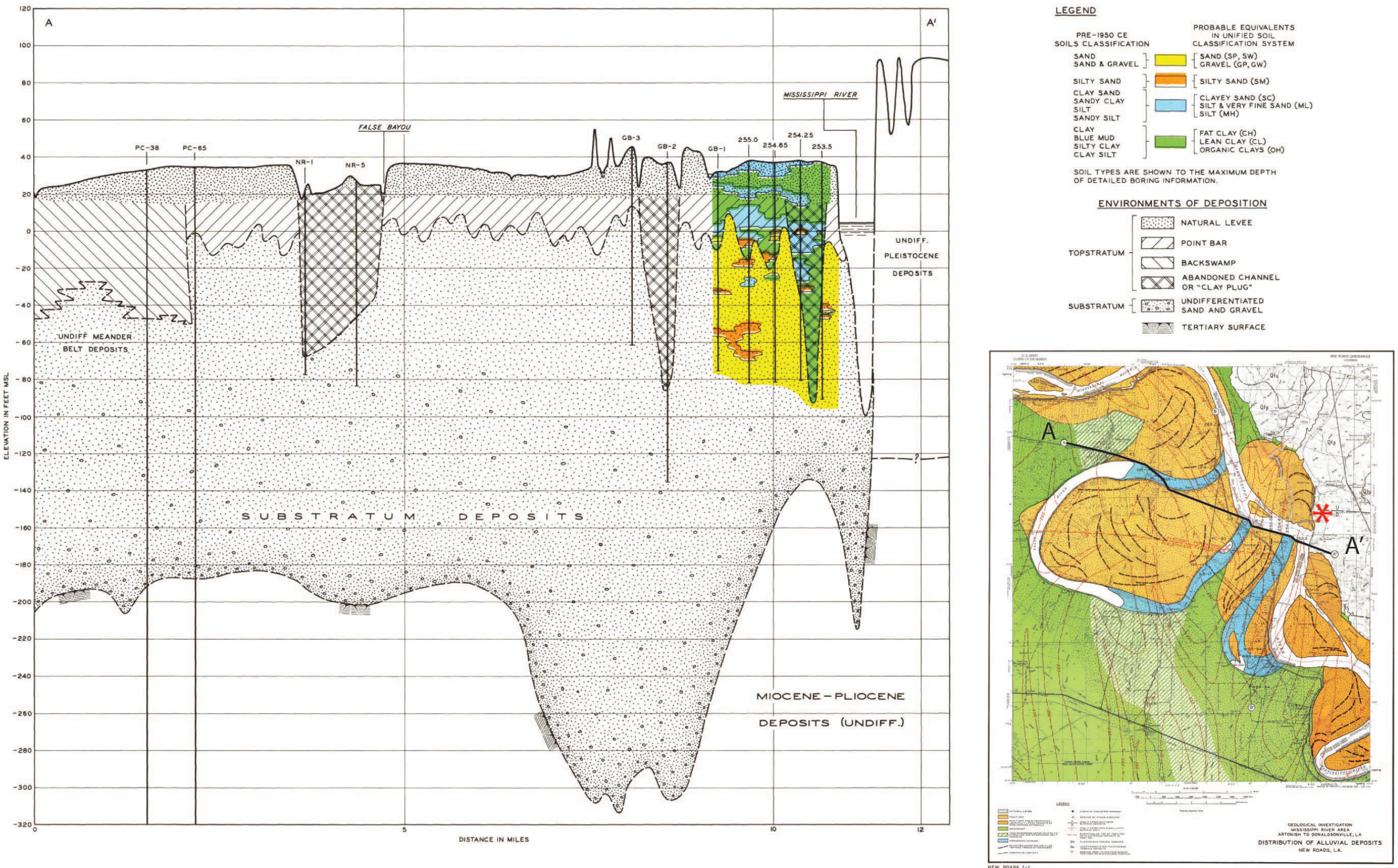


Figure 35: Geologic cross-section from New Roads to the Mount Pleasant Bluff; Port Hudson is labeled with a red asterisk (source: Saucier, 1969).

The Tuscaloosa Trend

The Tuscaloosa Trend play of Louisiana (Fig. 30) represents a narrow zone of oil and gas fields located along the lower Cretaceous shelf margin (Fig. 31). Growth faults present within this zone created structural traps where the oil and gas accumulated (Fig. 36). These traps are found within the Tuscaloosa Group and the Austin Group (also known as the Austin Chalk) of the upper Cretaceous System. The Tuscaloosa Group is older than the Austin Group, and is equivalent to the Woodbine Formation of Texas. The play is considered to be a deep play; most wells drilled in these traps range in depth between 15,000 and 20,000 feet. The play was initially discovered by Chevron U.S.A. Inc. near False River in Pointe Coupee Parish (Fig. 37).

The Port Hudson field was discovered by the AMOCO Production Company in December, 1977, and remains in production today (Fig. 38). Peak field production occurred in 1996 (Figs. 39 and 40). The Port Hudson field has two productive formations: the Tuscaloosa Reservoir A sandstones (~16,000 to 19,000 feet deep) and the Austin Chalk (~14,000 to 16,000 feet deep). The productive traps are the result of a combination of structural uplift and faulting associated with salt domes formation, and regional growth faulting associated with the lower Cretaceous shelf margin.

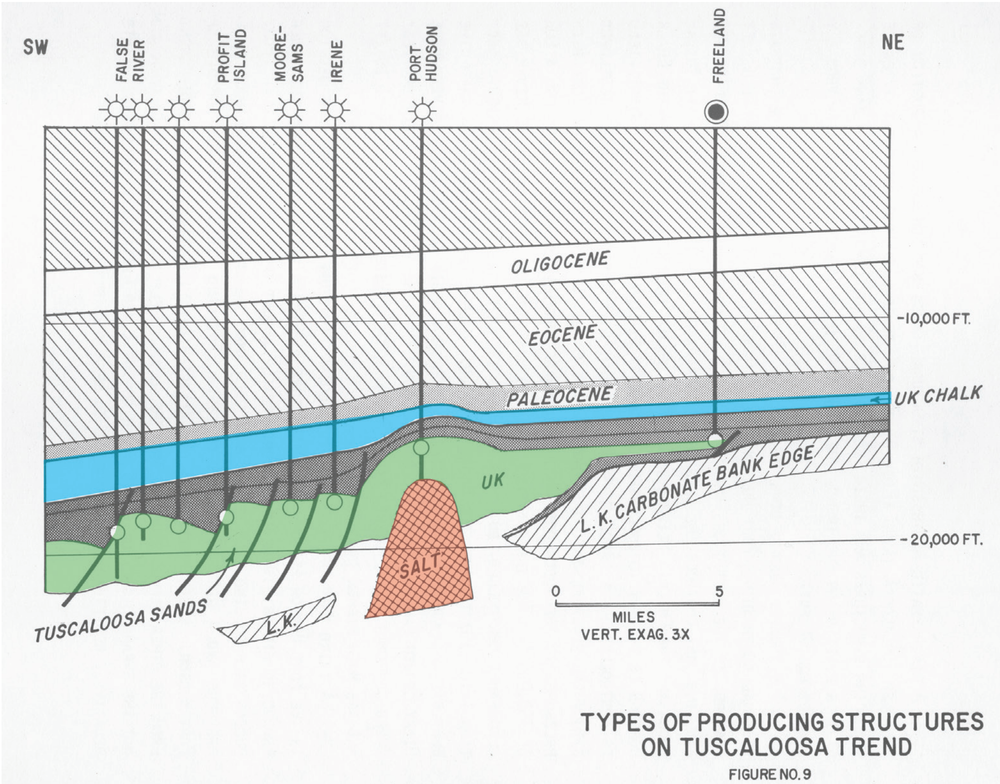


Figure 36: SW-NE cross section across the Tuscaloosa Trend at Port Hudson. The Tuscaloosa group is colored in green, the Austin Chalk in blue, and the Port Hudson Salt dome in orange (source: Steward, 1981, reproduced with permission from the New Orleans Geological Society).

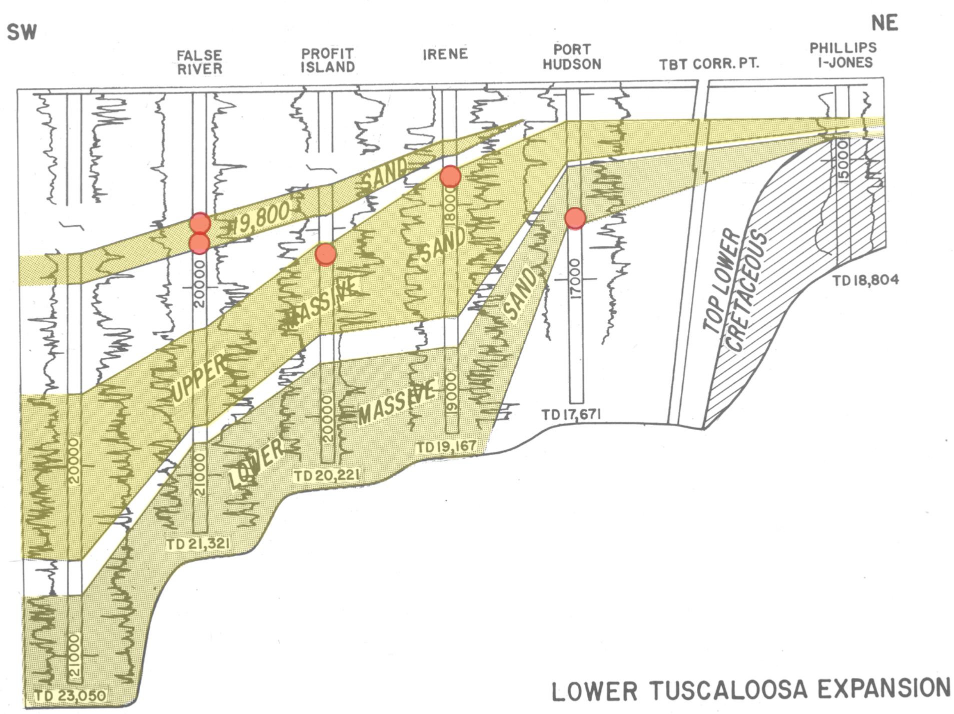


Figure 37: SW-NE cross section of the lower Tuscaloosa Group depicting the three producing sands. The sands are colored in yellow and the completion zones in orange (Source: Steward, 1981, reproduced with permission from the New Orleans Geological Society).

The Tuscaloosa Group

The Tuscaloosa Group (Figs. 36 and 37), similar to the Wilcox Group, was formed in a shallow marine fluvio-deltaic environment. It is composed of interbedded layers of fine- and coarse-grained beds, and shales (Eagle Ford Shale and Pepper Shale). Because of the depth, the coarse-grained layers are commonly referred to be sandstone-like. The massive basal layer of the Tuscaloosa Group is composed of coarse sands and gravels, and is considered to be one of the more productive portions of the unit. The provenance of the oil in the Tuscaloosa sand layers is thought to be the many interbeds of shale within the formation. The source of gas is most likely the same, however some of the gas may have migrated into the Tuscaloosa from other formations.

The Austin Group

The Austin Group (Fig. 36) is a deep marine carbonate (e.g., limestone) formation composed of interstratified chalks [dominantly composed of microfossils (e.g. foraminifers, plankton, etc.)] and marls (dominantly composed of clay). The unit has low porosity, but is heavily fractured. The source of the hydrocarbons in the Austin Chalk is the chalk and marl layers, and, to a lesser degree, the Eagle Ford Shale located below. It should be noted that in Mississippi, the Austin Chalk and Eagle Ford Shale are combined into the Eutaw Formation.

The Port Hudson Salt Dome

The Port Hudson salt dome (Figs. 34 and 36) is located beneath the Georgia Pacific, LLC property. The top of the dome has a depth estimated at 20,000 feet. As indicated earlier, this dome is formed by the movement of a portion of Jurassic System Louann Salt upward relative to other sedimentary formations. This fluid movement of salt is caused by the fact that salt is less dense than the sediment deposits surrounding it. The movement causes the formations above the salt to bow upward, causing the faulting of these sediments, as they are pushed aside. Salt fluidity at depth is considered to be a function of (1) the density contract between the lighter salt and the heavier surrounding rock; (2) the high heat conductivity of salt as a material; and (3) the ability of salt to flow or migrate plastically in the subsurface at the geothermal gradients and geopressure observed in this part of the Gulf of Mexico.

Vc. Natural Resources

Energy Resources

The study area (Fig. 38) encompasses the port Hudson oil and gas field (LDNR field #7521). The field depicted on Figure 38 included the currently active portion, which exploits the Tuscaloosa Trend (Figs. 39 and 40). Farther south, toward the Irene salt dome, wells are drilled into the Wilcox Group. As mentioned earlier in this report, based upon the Louisiana Department of Natural Resources' Strategic Online Natural Resources Information System (SONRIS), peak production at the field (Fig. 36) was reached in 1996 at 5,424,324 barrels (bbls), while natural gas peaked in 1999 at 50,785,428 million cubic feet (mcf). Cumulative production (Fig. 37) indicates that, as of 2009, 68 wells had been drilled into the field with a total oil and gas production of 90,693,982 bbls (2008 total), and 803,636,706 mcf (2009 total), respectively.

Non-Energy Resources

Within the study area, there are few non-energy resources. Sand and gravel can be found locally at shallow depth or along Thompson and other creeks. These sand and gravel deposits are mined for road bed construction. Although present in association with the Port Hudson dome, salt and sulfur are not exploited due to the depth of the salt dome. The nearby, and much shallower, Irene Salt dome is also too deep (~8,000 feet) for exploitation. As indicated in the historical section of this report, the bluff basal clay was quarried in the early days (pre Civil War) to make pottery.

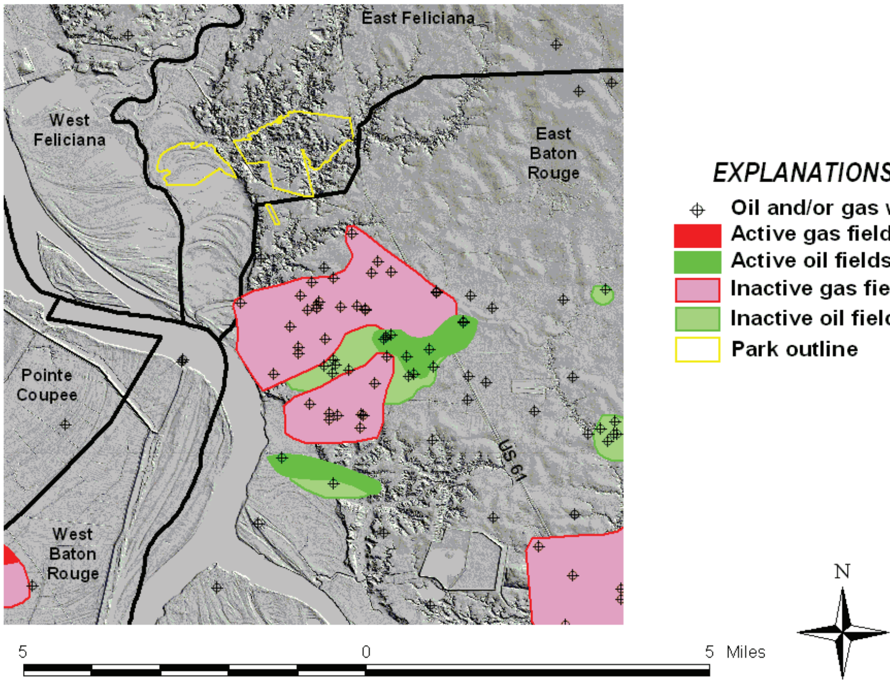


Figure 38: Locations of the Port Hudson oil and gas field (middle of the figure) near the Port Hudson Battlefield.

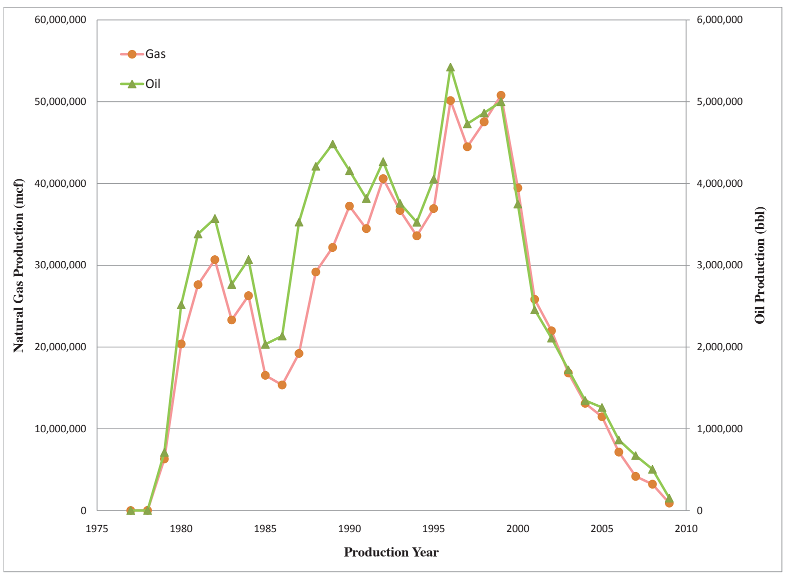


Figure 39: Oil and gas production from the Port Hudson field (source: LDNR, 2009a).

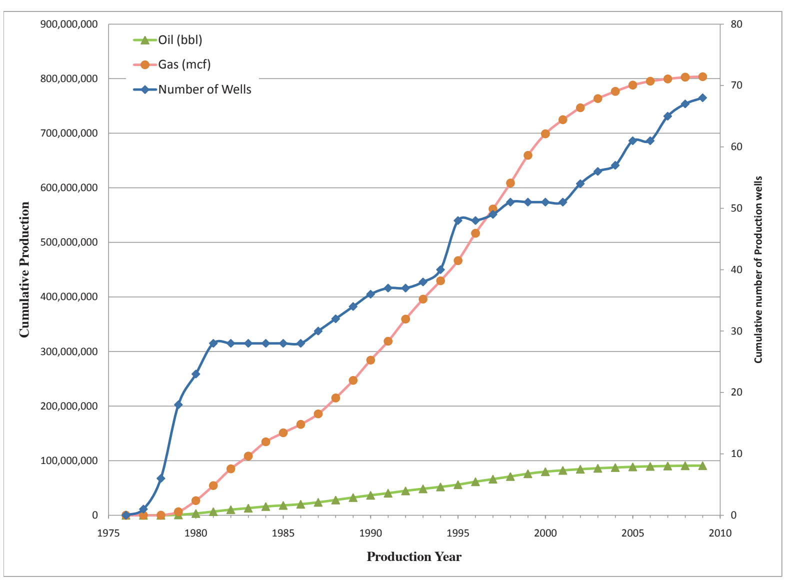


Figure 40: Cumulative oil and gas production from the Port Hudson field (Source: LDNR, 2009a and 2009b).

Geohydrology

Groundwater Resources

The area surrounding Port Hudson has expansive groundwater resources. Beneath the surface lie the ten named aquifers (i.e. freshwater-bearing sands) of the Southern Hills Aquifer System. In addition, the upper part of the Catahoula Aquifer may regionally contain freshwater (Table 4). Locally, the two upper aquifers are equivalent to the "400-foot sand" and "600-foot sand" of Baton Rouge, and are called "Shallow Sand." It should be noted that the names given to aquifers in the Baton Rouge area are based upon the depths of the sands at a water supply well (EB-534) located in the industrial park north of the city center. Because the sands dip at an angle of ~25°, this depth-based nomenclature can result in confusion outside the immediate area of downtown Baton Rouge. The 400-foot Sand of Baton Rouge is ~ 80-135 feet below the ground surface, and the 600-foot Sand of Baton Rouge is 300-400 feet below the ground surface at the Georgia Pacific plant. In other words, in the Port Hudson area, the various sands are found 200 to 300 feet shallower than their names would suggest.

Table 4: Generalized Aquifer Designation in Southeastern Louisiana

		Mississippi River Valley	New Orleans Area	Baton Rouge Area	Western Florida Parishes	Eastern Florida Parishes	Mississippi State	Geologic Age
Recent Alluvium	Southern Hills Aquifer System	Mississippi River Alluvial	Shallow Sand	Shallow Sand	Shallow Sand	Shallow Sand	Post-Graham Ferry	Holocene
Chicot Equivalent			Gramercy					Pleistocene
			Norco					
			Gonzales-New Orleans					
Evangeline Equivalent			1,200-Foot Sand	400-foot Sand	Upland Terrace	Upper Ponchatoula	Citronelle	Pliocene
				600-Foot Sand	Upper Ponchatoula		Upper Graham Ferry	
				800-Foot Sand	Lower Ponchatoula	Lower Ponchatoula	Lower Graham Ferry	
		1,000-Foot Sand		1,000-Foot Sand				
		1,200-Foot Sand		1,200-Foot Sand		Big Branch		
Jasper Equivalent		1,500-Foot Sand		1,500-Foot Sand	Kentwood	Abita	Upper Pascagoula	Miocene
		1,700-Foot Sand		1,700-Foot Sand		Covington	Lower Pascagoula	
					Slidell	Slidell		
		2,000-Foot Sand		2,000-Foot Sand	Hammond	Tchefuncte/ Hammond	Upper Hattiesburg	
		2,400-Foot Sand		2,400-Foot Sand	Amite	Amite		
		2,800-Foot Sand		2,800-Foot Sand	Ramsay	Ramsay	Lower Hattiesburg	
Catahoula Equivalent		Catahoula		Catahoula	Franklinton	Franklinton	Upper Catahoula	
							Lower Catahoula	Oligocene

Source: Modified from Van Biersel et al, 2009.
Note: Eastern Feliciana Parishes include St. Tammany, Tangipahoa, and Washington parishes; and the Western Florida Parishes include East Baton Rouge, East Feliciana, West Feliciana, Livingston, and St. Helena parishes.

Based upon the LDOTD water well database, there are 158 existing registered wells in the two townships and one range encompassing the study area (T 04S R 02W and T 05S R 02W). This number does not include wells drilled prior to 1983, and therefore not registered, or wells that have been abandoned, excavated or destroyed. There are 111 environmental wells (94 monitoring wells, 5 recovery wells and 12 piezometers), 30 industrial wells, 6 public supply wells, five domestic wells, two other-use wells, one irrigation well, and one rig-supply well. Figure 41 shows the distribution of water supply wells in the vicinity of Port Hudson.

The local groundwater usage can be estimated by compiling the information collected by the Capital Area Ground Water Conservation Commission. This commission is a management district established in 1974 by the Louisiana legislature, which includes East Baton Rouge, East Feliciana, Pointe Coupee, West Baton Rouge and West Feliciana parishes. The Commission collects data from the larger ground water producers/users. Based upon their database, which includes 21 large-capacity wells near the Park, peak groundwater withdrawal occurred in 2002 at 15,641,625,000 gallons [or ~42,854,000 gallons per day (gpd) or ~30,000 gallons per minute (gpm) - Fig. 42]. The groundwater is pumped predominantly from the 2,800-Foot sand (35%), the 400 and 600-Foot sands (32%), and the 1,500 and 1,700-Foot sands (29%). In addition, the 1,000 and 1,200-Foot sands are pumped to a lesser degree (4%).

Locally, the 2,800-Foot, the most prolific sand, is found at a depth of 2,270 feet, and it is thickest at more than 330 feet thick. The 2,800-Foot sand appears to be in direct hydraulic contact with the Catahoula Aquifer below. The 400 and 600-Foot sands are also very prolific. They are very shallow (80-135 feet deep) and have a combined thickness of ~200 feet. The upper portion of the 400-Foot sand is in hydraulic contact with the Mississippi River alluvium (Mississippi River Valley Aquifer). The 1,500 and 1,700-Foot sands have a combined thickness of ~150 feet (the thickest layer is 85 feet thick), are composed of three sand layers, and are found at depths ranging from 980 to 1300 feet. The 1,200-Foot sand is composed of three layers with a combined thickness of 90 feet, at depths ranging from 640 to 800 feet deep. The 2,000-Foot sand is locally absent, and the 2,400-Foot sand has a thickness of only 20 feet.

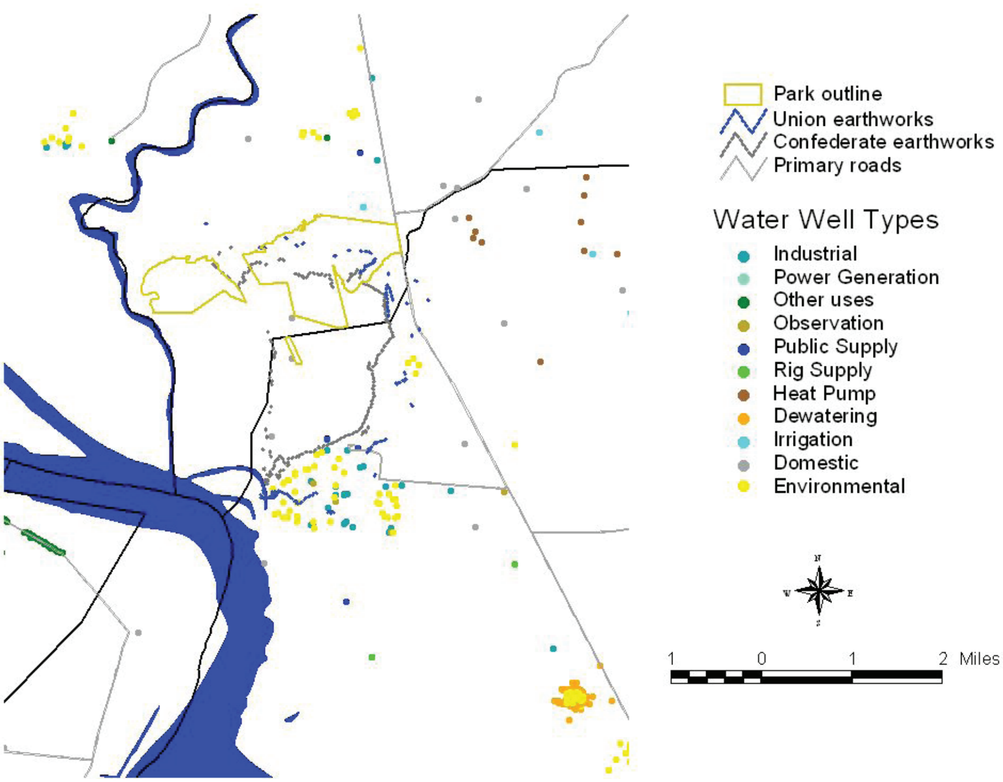


Figure 41: Distribution of existing water wells in the LDOTD database in the vicinity of Port Hudson (data source: LDOTD water well database dated 1/14/2010).

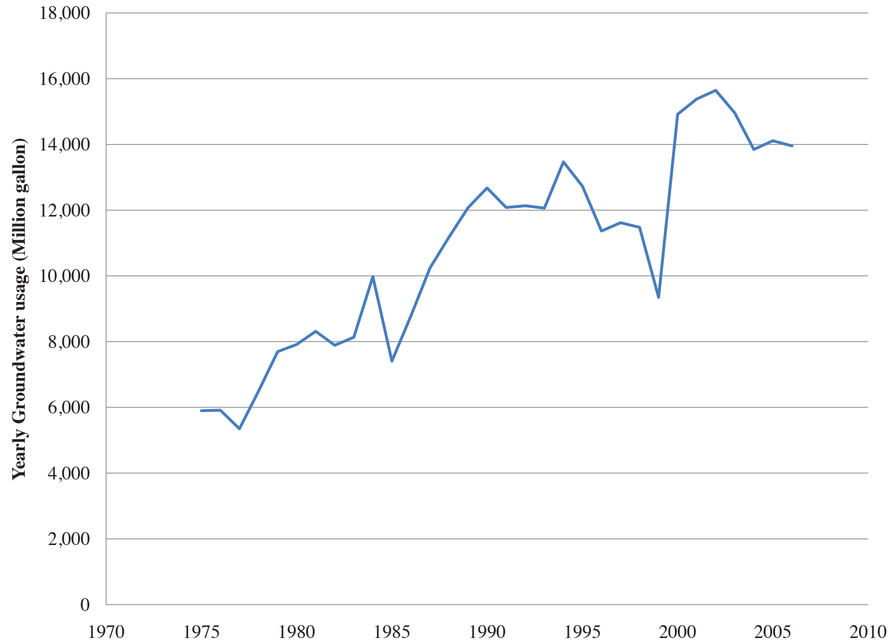


Figure 42: Groundwater pumpage from large capacity water supply wells in the study area (data source: Capital Area Ground Water Conservation Commission 2006 database).

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Appendix A: Historic Map

Map of Port Hudson and its defenses by Capt. Fremaux, 30 October 1862, Gilmer Map Number 408, OP-276/263, in the Jeremy Francis Gilmer Papers #276, Southern Historical Collection, Louis Round Wilson Special Collections Library, University of North Carolina at Chapel Hill; reproduced with permission.


A MAP of PORT HUDSON and its DEFENCES.
Note:- The leading & important Roads are indicated in Brown
The Neighborhood Roads in a single line of Red
SCALE OF FOUR INCHES TO ONE MILE.
Engineer's Office,
Port Hudson La
Octr 30th 1862
A true copy of the original on file in this Office
Capt & chief Engr
P.H. Fortns
True Meridian.
SANDY CREEK BRIDGE
Capt. Griffith.
Mrs Loudon
CULTIVATED
MUCH BROKEN BY RAVINES AND GULLIES AND WITH THICK WOODS
Head Quarters Brig. Gen. Beall
PORT HUDSON.
HILL ROAD TO JACKSON
PORT HUDSON AND CLINTON RAIL ROAD
ROAD TO CLINTON VIA PLAINS STORE
3rd Mile Post
2nd Mile Post
1st Mile Post
BATTERY No I.
BATTERY No II.
BATTERY No III.
Ferry Landing
BATTERY No IV.
BATTERIES V & VI.
BATTERY No VII.
BATTERY No IX.
BATTERY No X.
BATTERY No XI.
PRINCIPAL MAGAZINE
FLAT WOODS.
ROAD TO BATON ROUGE
Mr Slaughter's
Mr Montegudo
Mrs Woodside's Plantation
Overseers House
Gin House
Mr Hunt's
Gibbens' Gin House.
THICK WOODS
UNEVEN GROUND
CULTIVATED
WOODS
VERY ROUGH THICK WOODS BRIARY THICKETS
Mr Sherburne
Sherburne's Gin House.
FLAT WOODS
4th Mile Post
Mr Argo's
Newly Opened Road to Troth's Landing
School House
Mr J. D. Yerkes
Troth's Landing
Mr R. S. Troth
LAKE SOLITUDE.
5 & 7 feet deep – Muddy Bottom.
FLAT THICK WOODS
J. W. Cole.
FLAT WOODS
CYPRESS
LAKE
SWAMP
IMPASSABLE
THICK WOODS
MOBILE RIDGE
THICK WOODS, CANES, VINES
COOPER'S BAYOU
THICK WOODS, CANES, VINES
RAVINES AND GULLIES DENSELY WOODED
BATON ROUGE BAYOU
Lone Tree
Mr Bullers
LOW FLAT WOODS
Mr Newport
Mr Neville
Doctor Jones's.
CULTIVATED
VERY ROUGH HEAVILY WOODED
LILLY'S BAYOU
MUCH BROKEN
Road to Baton Rouge
James Lilly
Flat, thinly wooded
Briary Thickets
HEAVY VERY BROKEN WOODS BRIARY THICKETS
Road from Springfield Landing to Port Hudson
Mr Thomas Lilly
2 Miles further to Springfield Landing.
STEAMBOAT CHUTE
Capt. John Riley
Wm. M. New
Cultivated
WOODS

Appendix B: Custom Soil Resource Report

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Units

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other

Special Line Features
- Gully
- Short Steep Slope
- Other

Political Features
- Cities

Water Features
- Oceans
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads

MAP INFORMATION

Map Scale: 1:56,600 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 15N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: East Baton Rouge Parish, Louisiana
Survey Area Data: Version 6, Oct 1, 2007

Soil Survey Area: East Feliciana Parish, Louisiana
Survey Area Data: Version 2, Apr 12, 2007

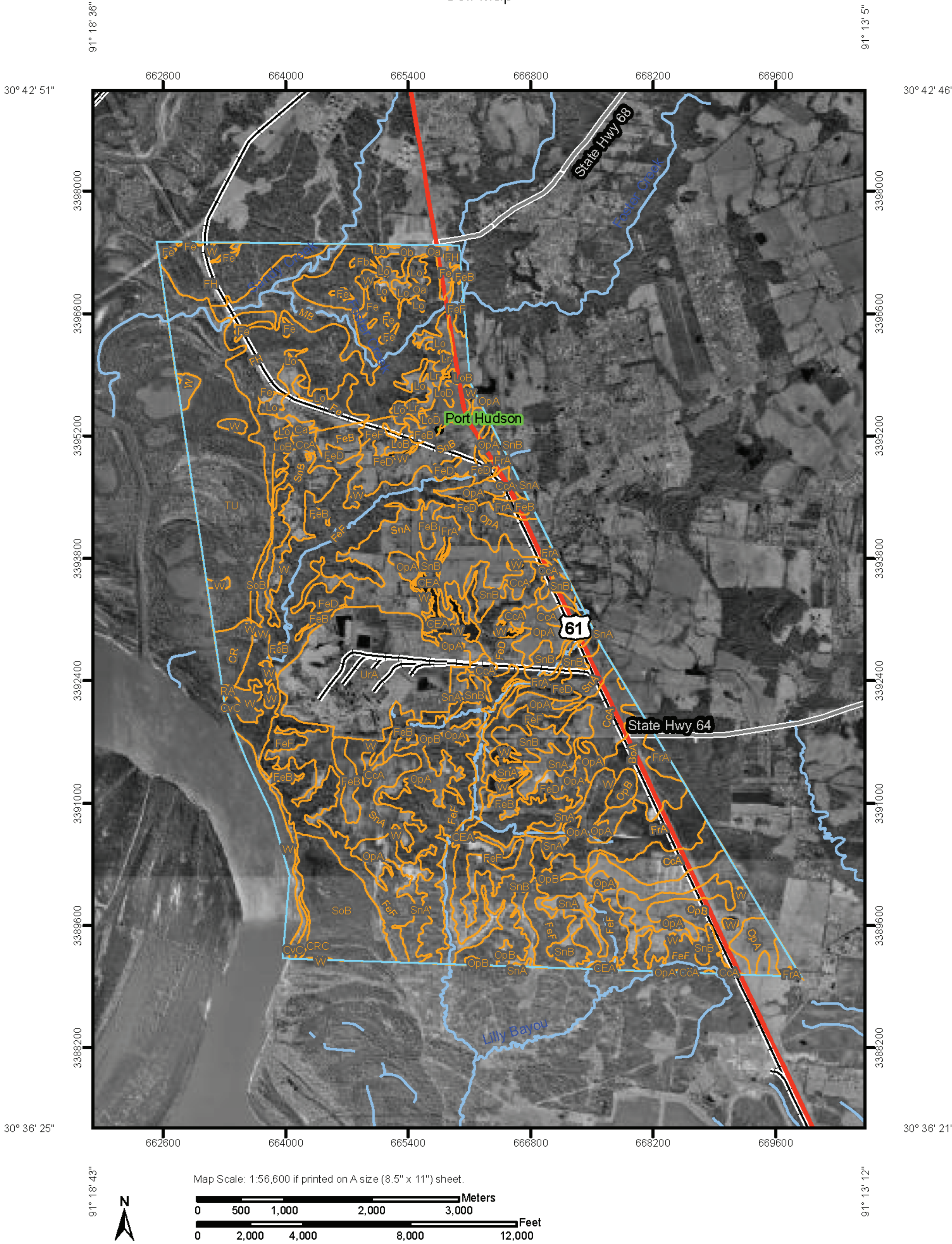
Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Date(s) aerial images were photographed: 1998

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

(source: excerpts from U.S. Dept. of Agriculture Natural Resources Conservation Service, Custom Soil Resource Report for East Baton Rouge Parish, Louisiana, and East Feliciana Parish, Louisiana, http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx, accessed 10/5/09)

Custom Soil Resource Report
Soil Map



Map Unit Legend

East Baton Rouge Parish, Louisiana (LA033)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
BoA	Bonn silt, 0 to 1 percent slopes	134.7	1.5%
CcA	Calhoun silt loam, 0 to 1 percent slopes	333.3	3.8%
CEA	Calhoun and Cascilla silt loams, frequently flooded	127.8	1.5%
CRC	Convent and Robinsonville soils, frequently flooded	10.2	0.1%
CvC	Crevasse fine sand, undulating, frequently flooded	125.8	1.4%
FeB	Feliciana silt, 0 to 3 percent slopes	203.0	2.3%
FeD	Feliciana silt loam, 3 to 8 percent slopes	240.5	2.7%
FeF	Feliciana silt loam, 8 to 30 percent slopes	1,606.2	18.3%
FrA	Frost silt loam, 0 to 1 percent slopes, occasionally flooded	347.2	4.0%
LoB	Loring silt loam, 1 to 3 percent slopes	95.2	1.1%
LoD	Loring silt loam, 3 to 8 percent slopes	14.8	0.2%
OpA	Oprairie silt, 0 to 1 percent slopes	576.1	6.6%
OpB	Oprairie silt, 1 to 3 percent slopes	329.5	3.8%
SnA	Scotlandville silt, 0 to 1 percent slopes	801.5	9.1%
SnB	Scotlandville silt, 1 to 3 percent slopes	701.7	8.0%
SoB	Sharkey-Tunica clays, gently undulating, frequently flooded	270.6	3.1%
UrA	Urban land	547.7	6.2%
W	Water	202.7	2.3%
Subtotals for Soil Survey Area		**6,668.5**	**75.9%**
Totals for Area of Interest		**8,786.3**	**100.0%**

East Feliciana Parish, Louisiana (LA037)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
Ca	Calhoun silt loam	10.2	0.1%
CR	Crevasse loamy sand, frequently flooded	54.8	0.6%
Fb	Feliciana silt loam, 0 to 1 percent slopes	5.2	0.1%
Fe	Feliciana silt loam, 1 to 3 percent slopes	155.5	1.8%
FH	Feliciana and Natchez silt loams, steep	838.3	9.5%
Lo	Loring silt loam, 1 to 3 percent slopes	147.5	1.7%
Lr	Loring silt loam, 3 to 8 percent slopes	16.2	0.2%
MB	Morganfield and Bigbee soils, frequently flooded	185.6	2.1%
Oa	Olivier silt loam, 0 to 1 percent slopes	5.5	0.1%
Ob	Olivier silt loam, 1 to 3 percent slopes	27.8	0.3%
RA	Riverwash	2.5	0.0%

Port Hudson Bluff circa 1863 (Louisiana Historical Photographs Collection of the State Library of Louisiana; reproduced with permission).

Port Hudson earthworks circa 1863 (Marshall Dunham Photograph Album, Mss 3241, Louisiana and Lower Mississippi Valley Collections, LSU Libraries, Baton Rouge, LA; reproduced with permission).

View of the Port Hudson bluff near the old landing looking south in 1863 (John Langdon Ward Lantern Slides, Mss. 4875, Louisiana and Lower Mississippi Valley Collections, LSU Libraries, Baton Rouge, LA; reproduced with permission).

View of the Port Hickey landing in 1863 (Source: Louisiana Historical Photographs Collection of the State Library of Louisiana; reproduced with permission).

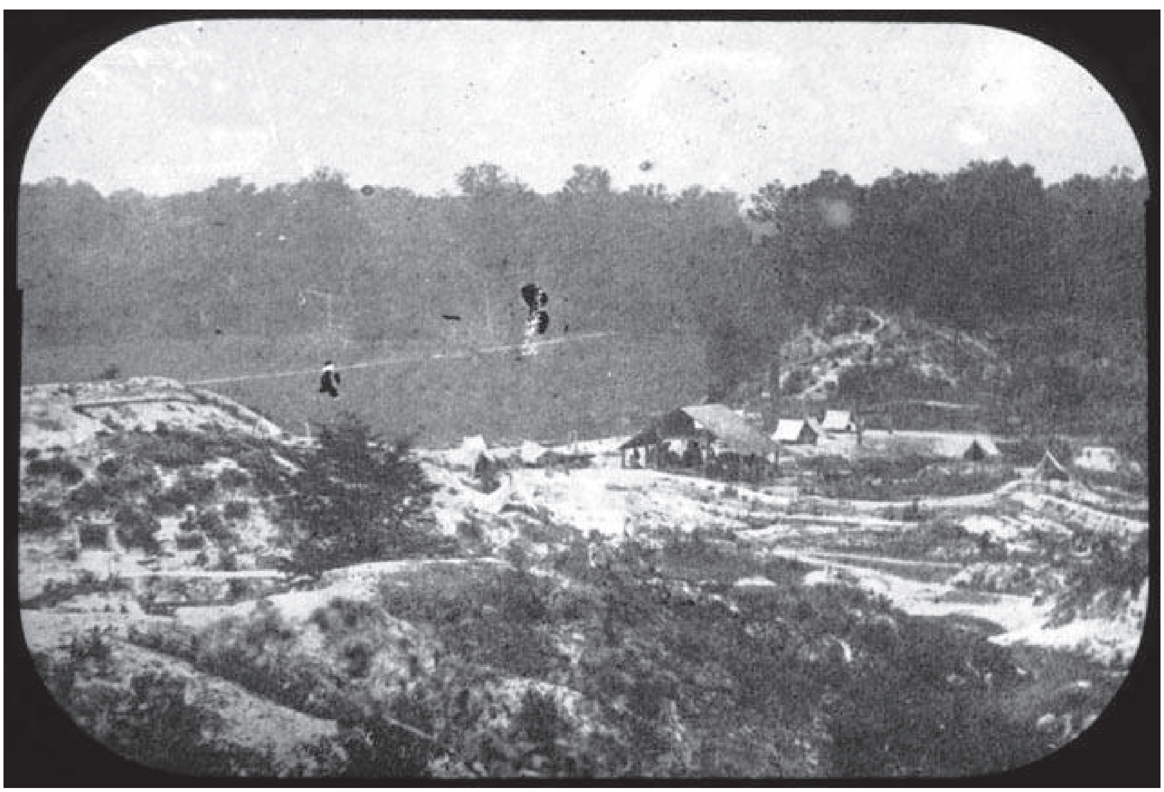
Fortifications at Port Hudson Louisiana during the Civil War (Source: Louisiana Historical Photographs Collection of the State Library of Louisiana; reproduced with permission).

View of the fortification near the Jackson Road sally port in 1863 (John Langdon Ward Lantern Slides, Mss. 4875, Louisiana and Lower Mississippi Valley Collections, LSU Libraries, Baton Rouge, LA; reproduced with permission).

View from a bluff battery in 1863 (John Langdon Ward Lantern Slides, Mss. 4875, Louisiana and Lower Mississippi Valley Collections, LSU Libraries, Baton Rouge, LA; reproduced with permission).

Photograph of most probably the interior of the Citadel in 1863; note the bluff in the background and the gopher holes (John Langdon Ward Lantern Slides, Mss. 4875, Louisiana and Lower Mississippi Valley Collections, LSU Libraries, Baton Rouge, LA; reproduced with permission).

Photograph of the north fortifications in 1863 showing the difficulty of the terrain (John Langdon Ward Lantern Slides, Mss. 4875, Louisiana and Lower Mississippi Valley Collections, LSU Libraries, Baton Rouge, LA; reproduced with permission).



Photograph of the northwest terrain (in 1863) where the Corp d'Afrique launched their assaults (John Langdon Ward Lantern Slides, Mss. 4875, Louisiana and Lower Mississippi Valley Collections, LSU Libraries, Baton Rouge, LA; reproduced with permission).

Early 1900's picture of the Alto or Fontania (?) landing access road. For scale note the person at the base of the bluff (photographer unknown; courtesy of Port Hudson State Historic Site, Jackson, LA).

Early 1900's picture of the base of the bluff (photographer unknown; courtesy of Port Hudson State Historic Site, Jackson, LA).

Early 1900's picture of the top of the bluff (photographer unknown; courtesy of Port Hudson State Historic Site, Jackson, LA).

Appendix D: Related Websites Links

State Park Information:

Louisiana Department of Culture, Recreation & Tourism Office of State Parks http://www.crt.state.la.us/parks/ipthudson.aspx

National Park Service http://www.nps.gov/history/nr/travel/louisiana/por.htm

Civil War Information:

Battle of Jackson Cross Road http://www.battleofjacksoncrossroads.org/

National Park Service http://www.nps.gov/history/hps/abpp/battles/bystate.htm

Port Hudson Battlefield http://www.where2guide.com/TouristTrail/outdoors/PortHistory.html

Siege of Port Hudson http://www.historynet.com/siege-of-port-hudson.htm

The Battle of Port Hudson http://pth.thehardyparty.com/index.htm

The Louisiana Native Guards http://www2.netdoor.com/~jgh/

The siege of Port Hudson http://www.civilwar.org/battlefields/port-hudson.html

U.S. Army http://www.history.army.mil/books/AMH/amh-toc.htm

U.S. Navy http://www.history.navy.mil/wars/index.html

Teaching Material:

National Park Service "The Siege of Port Hudson: Forty days and night in the wilderness of death http://www.nps.gov/history/nr/twhp/wwwlps/lessons/71hudson/71hudson.htm

Teaching American History http://www.lpb.org/education/tah/

Others Sources:

Nicholas La Salle, Journal, 1682 http://www.tsl.state.tx.us/treasures/giants/lasalle/lasalle-cover.html

Louisiana Digital Library http://louisdl.louislibraries.org/

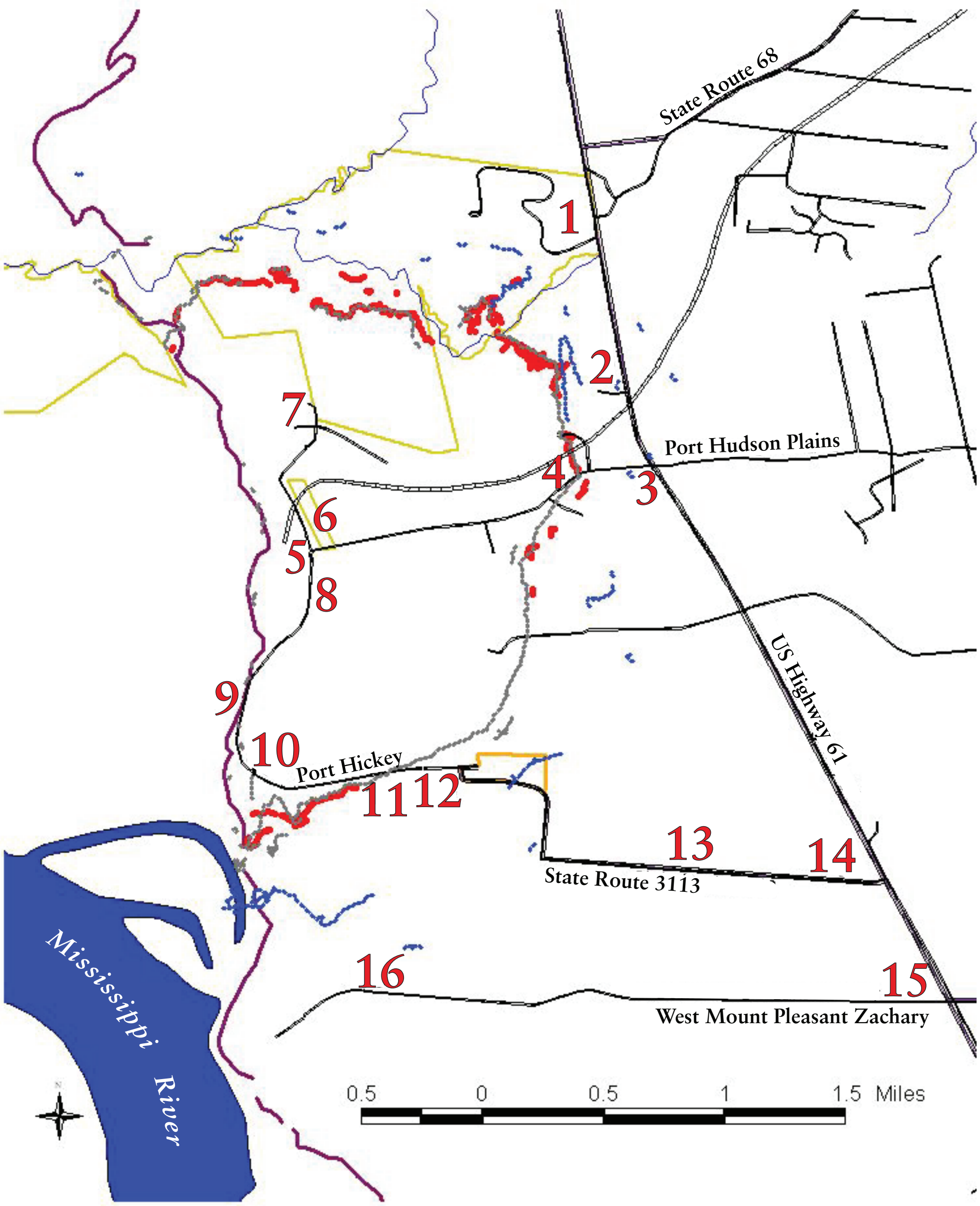
Google books http://books.google.com/

Port Hudson National Cemetery http://www.cem.va.gov/CEMs/nchp/porthudson.asp#gi

Appendix E: Self-Guided Driving Trip

This self guided field trip of the Port Hudson Battlefield and surrounding areas is based upon a similar document entitled "Battlefield Features of the Siege of Port Hudson" prepared by the Interpretive Staff of the Port Hudson State Commemorative Area and the Louisiana State Park.

CAUTION: With the exception of the Park and the Port Hudson National Cemetery, all other properties are privately owned; please be courteous and do not trespass onto these properties. This driving tour can also be done using Google(tm) Earth. Please note that this trip is valid as of 2009; please use good judgment if certain conditions may have changed along the route. Please stay in your car as the roads are narrow and do not have shoulders.



#1 Port Hudson State Historic Site

#2 View of the old Jackson Road sally port from U.S. 61 looking west-southwest

#3 View of West Plains-Port Hudson Road from across U.S. 61 (looking west)

#4 View of the West Plains-Port Hudson Road sally port

#5 Intersection of West Plains-Port Hudson and Port Hickey roads (looking west)

#6 Intersection of West Plains-Port Hudson and Port Hickey roads (looking north)

#7 Downtown old Port Hudson

#8 Location of the Confederate forces surrender

#9 Locations along where the Port Hickey Road is directly along the bluff

#10 Georgia Pacific LLC pavilion on Devil's Elbow.

#11 Location of preserved Confederate earthworks and an early 1900's cemetery

#12 Main entrance to the Port Hudson National Cemetery

#13 Slaughter's fields (view looking north from Port Hudson Cemetery Road)

#14 Location of the crossing of the Zachary Fault relative to U.S. 61 (Samuel Road).

#15 West Mount Pleasant Zachary Road

#16 End of the West Mount Pleasant-Zachary Road (looking toward the west)

1

Port Hudson State Historic Site

View from the observation tower near the visitor center looking north-northeast.

The Park's entrance from across U.S. 61 (looking west).

2

View of the old Jackson Road

sally port from U.S. 61 looking west-southwest

Earthworks along the tree line

3

West Plains-Port Hudson Road from across U.S. 61 (looking west)

4

West Plains-Port Hudson Road sally port

Confederate earthworks

5 Intersection of West Plains-Port Hudson and Port Hickey roads
(looking west)

Old access road to the Port Hudson/Alto Landing

6 Intersection of West Plains-Port Hudson and Port Hickey roads (looking north)

Confederate Gen. Gardner's headquarter and railroad depot was along the west side of the road.

The Clinton/Port Hudson railroad crossed the Port Hickey Road shortly after the turn.

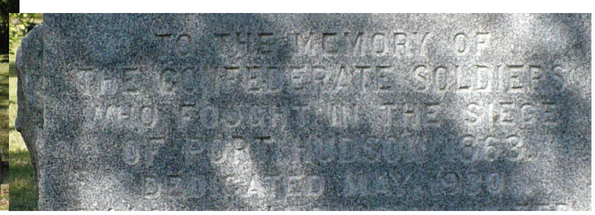
7

Downtown old Port Hudson

The McCallum house (circa 1845). This private home is one of the two remaining structures of the old town.

To the east of the renovated galleried cottage is the monument erected by the Daughters of the Confederacy in May 1930.

This is not the original location of the monument which was moved and stored prior to this emplacement. The road you are on is the old landing's access road.



8

Location of the Confederate forces surrender.

Looking south along the Port Hickey Road. The surrender ceremony occurred on the east side of the road.

9 Locations along where the Port Hickey Road is directly along the bluff.

Looking north along Port Hickey Road you can see a portion of the road that is being undermined by the collapsing bluff.

Looking south you can see a vista overlooking the Mississippi (overgrown most of the time).

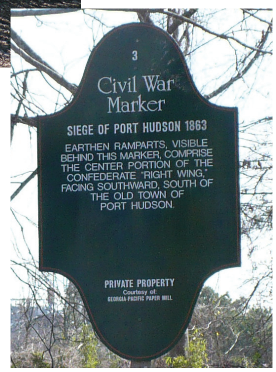
10 Georgia Pacific LLC pavilion

on Devil's Elbow.

Behind the pavilion (private property)is the preserved gun emplacement of the Boone Brigade (Eagle Scout project).

11

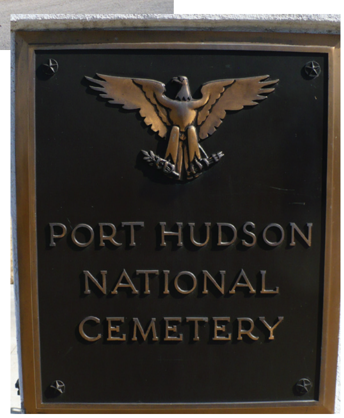
Location of preserved Confederate earthworks and an early 1900's cemetery.



12

Main entrance to the Port Hudson National Cemetery

Nearly 4,000 Union soldiers were buried here (only 600 were identified). Source: http://www.cem.va.gov/cems/nchp/porthudson.asp#gi



13

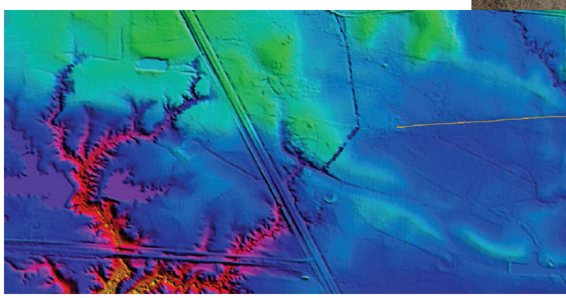
Slaughter's fields

(view looking north from Port Hudson Cemetery Road)

14

Location of the crossing of the Zachary Fault relative to U.S. 61 (Samuel Road).

The rise in grade of Samuel road coincides approximately with the fault location (photograph looking north from the intersection of Port Hudson Cemetery Road and U.S. 61).



15

West Mount Pleasant Zachary Road (looking toward the west from the intersection of US 61 and LA 64).

Pump jack pumping oil from the Wilcox Group above the Port Hudson salt dome.

16

End of the West Mount Pleasant-Zachary Road (looking toward the west).

The Mount Pleasant bluffs are 0.5 mile to the southwest (private property).

Louisiana Geological Survey

Chacko J. John,
Director & State Geologist

Design: Lisa Pond

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