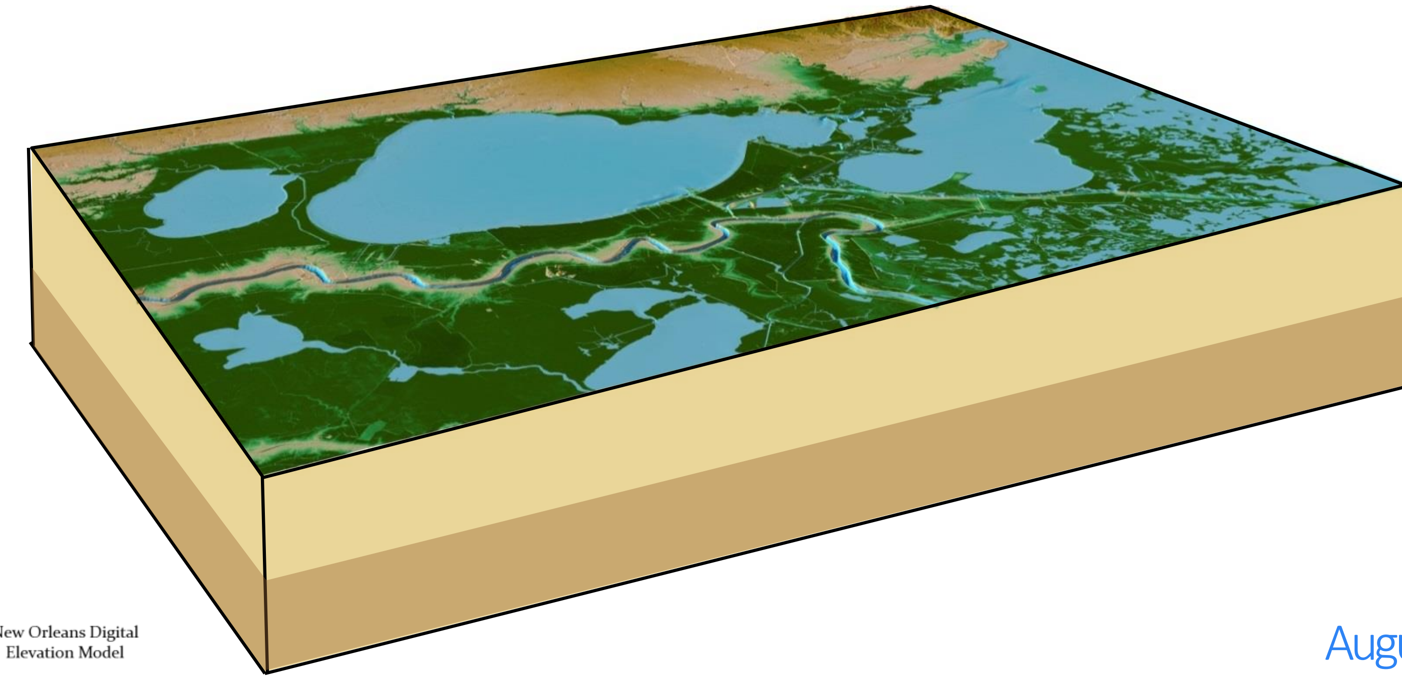
The Geology of New Orleans – Implications for Planners



New Orleans Digital Elevation Model

August 31, 2016

APA

American Planning Association

Making Great Communities Happen

The following set of slides were used by Chris McLindon in a presentation given to the Metro section of the American Planning Association on August 31, 2016. This presentation was made on behalf of the New Orleans Geological Society as a part of an informal public outreach effort in which members of the society may from time to time make public presentations on geology.

At the request of several of those in attendance at the APA presentation these slides have been annotated to allow them to be shared without a presenter. This set of annotated slides is not to be considered a publication of the New Orleans Geological Society. It has not been approved for publication by the Board of Directors of the Society. As with the presentation, this is strictly the work of Chris McLindon, and beyond the informal public outreach effort encouraged by the New Orleans Geological Society, he represents no other entity than himself.

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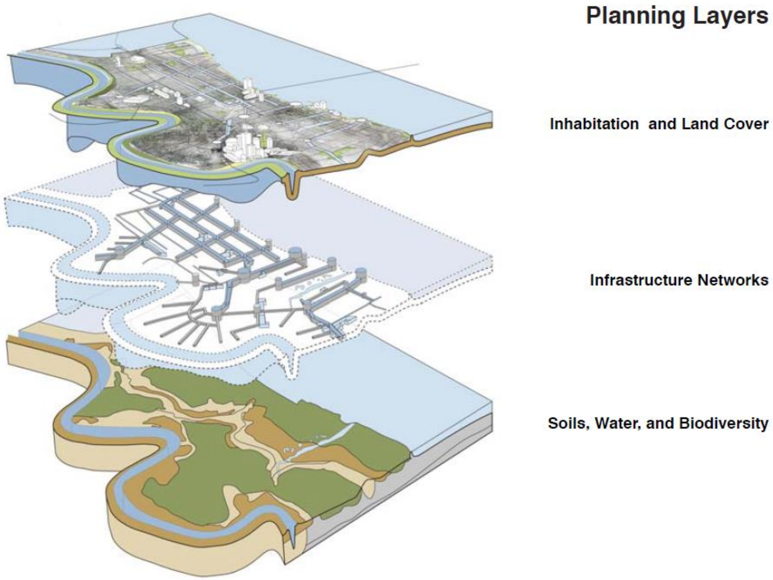
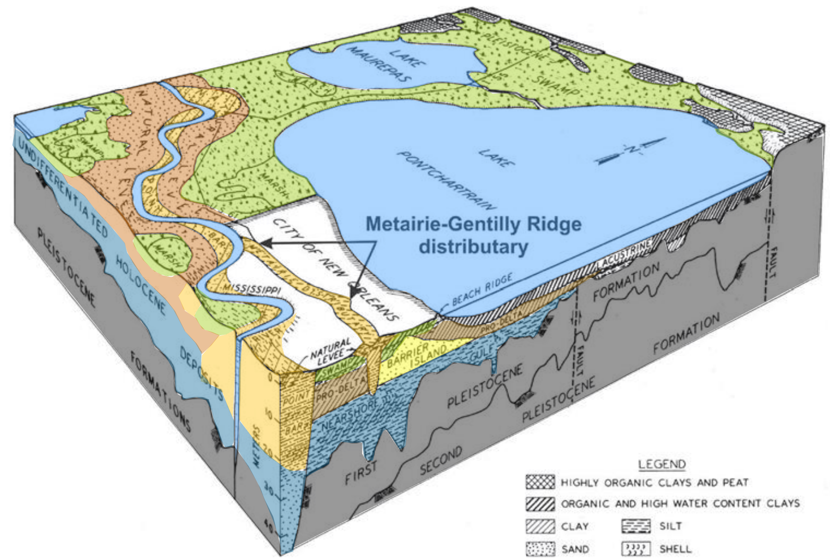
Urban Water Plan

Approach water from the ground up





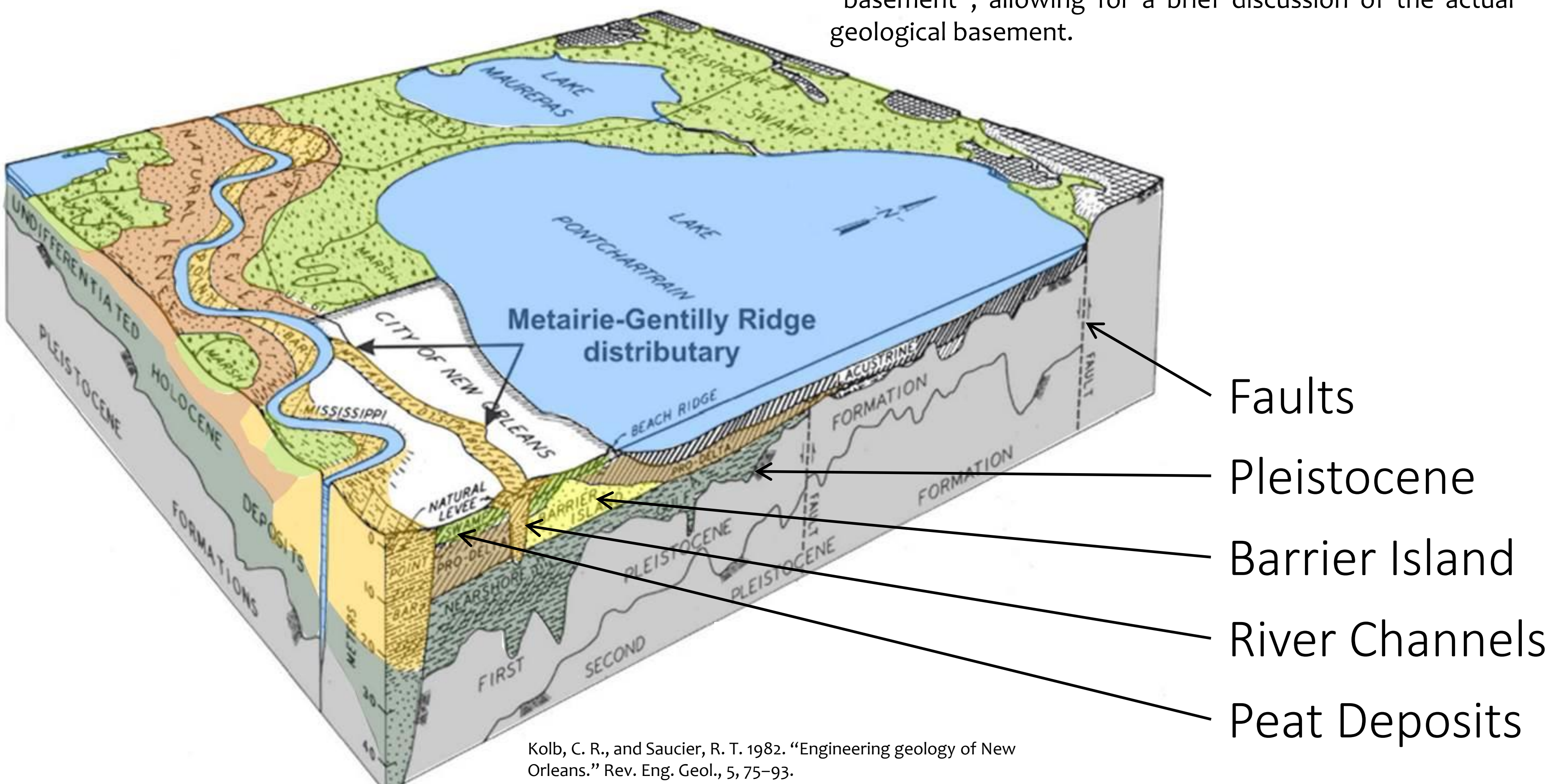
The Urban Water Plan is a model for sustainable management of a delta city. This presentation seeks to build on the Plan's "ground up" approach to water management by considering the implications of what is below the ground.

Adding a Dimension

below the ground down

New Orleans
below the surface

The presentation will discuss these five essential elements of New Orleans' subsurface geology above the Pleistocene surface, which for this purpose can be treated as geological "basement", allowing for a brief discussion of the actual geological basement.



Kolb, C. R., and Saucier, R. T. 1982. "Engineering geology of New Orleans." Rev. Eng. Geol., 5, 75–93.

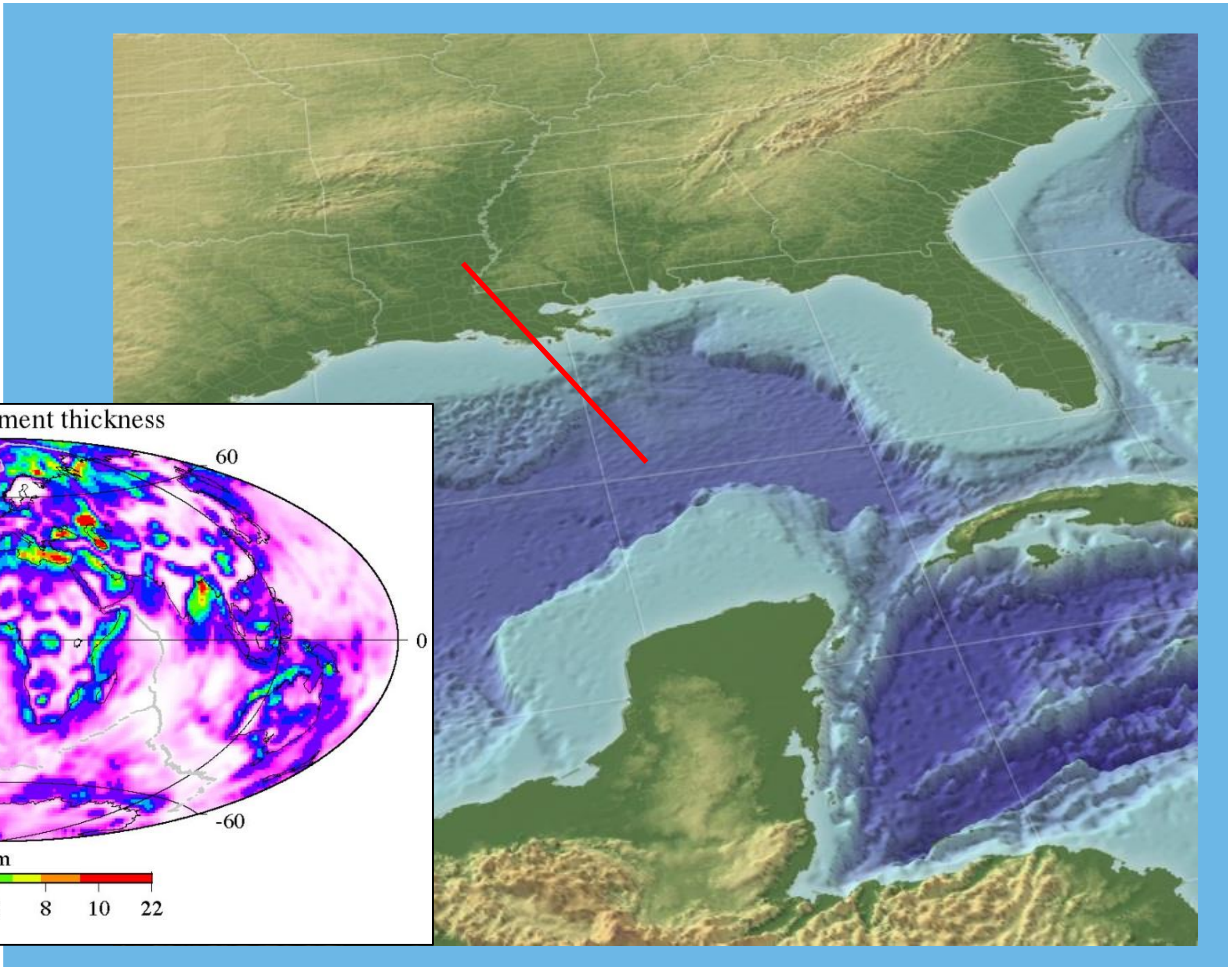
Building Louisiana

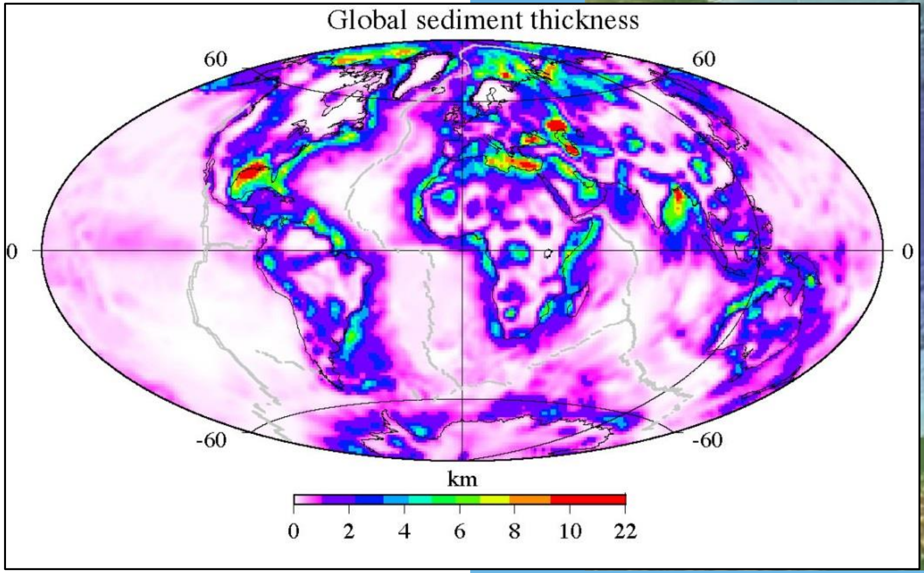
changes in geologic time

New Orleans is often referred to as the northern-most Caribbean port and as a delta city. It is also one of the largest city within the largest sedimentary basin in the world – the Gulf of Mexico Basin.

Building Louisiana
changes in geologic time

An estimated 12 miles of total accumulated sediment thickness lies in the center of the basin just south of the city. The red line is location of the profile on the succeeding slides.



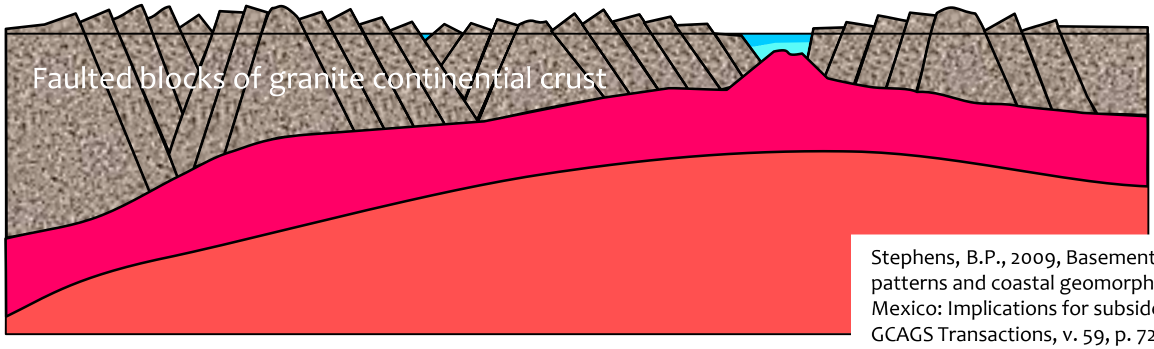


220 mya

Ron Blakey, Colorado Plateau Geosystems, Arizona USA, 2011

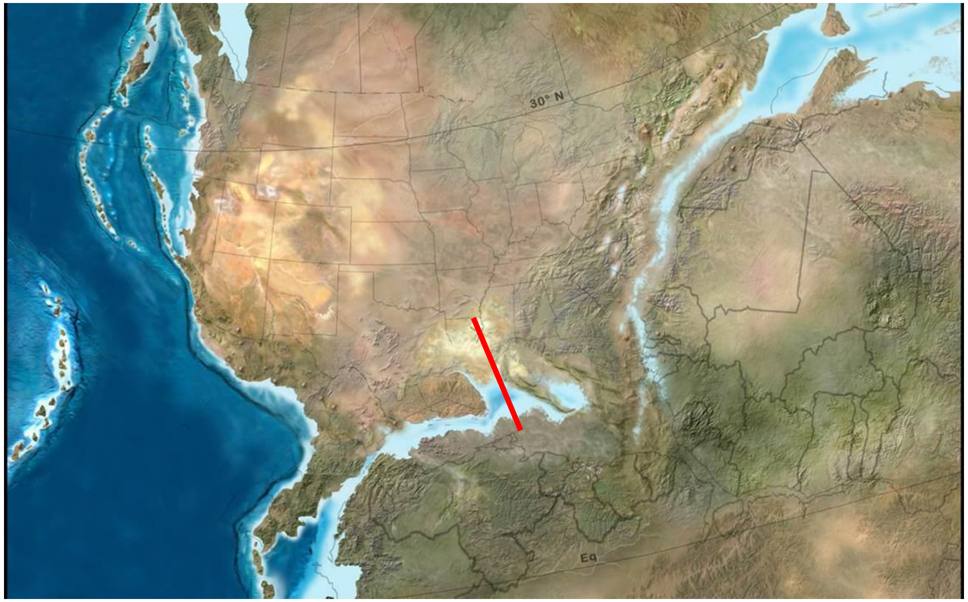
The following is a sequence of paleo- geographic reconstructions of the continental plates showing the opening of the Gulf of Mexico Basin. The age of each reconstruction is shown in the upper left as mya – million years ago.

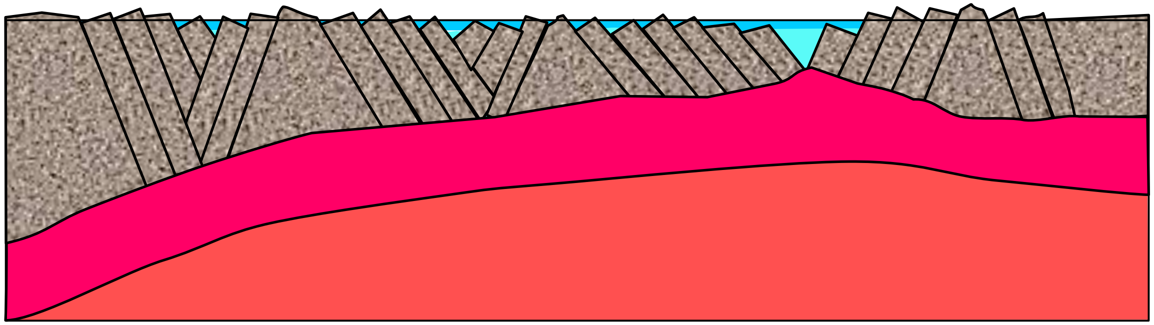
Beginning in the Triassic Period North America, Africa and South America were all together and what would become the basin was set of faulted granite blocks of continental crust



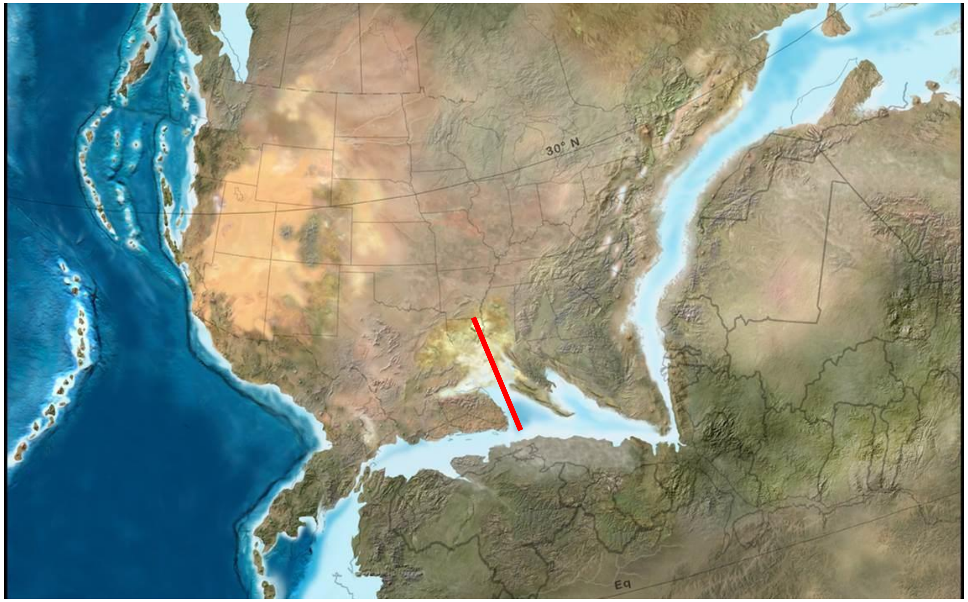
Stephens, B.P., 2009, Basement controls on subsurface geologic patterns and coastal geomorphology across the northern Gulf of Mexico: Implications for subsidence studies and coastal restoration, GCAGS Transactions, v. 59, p. 729-751

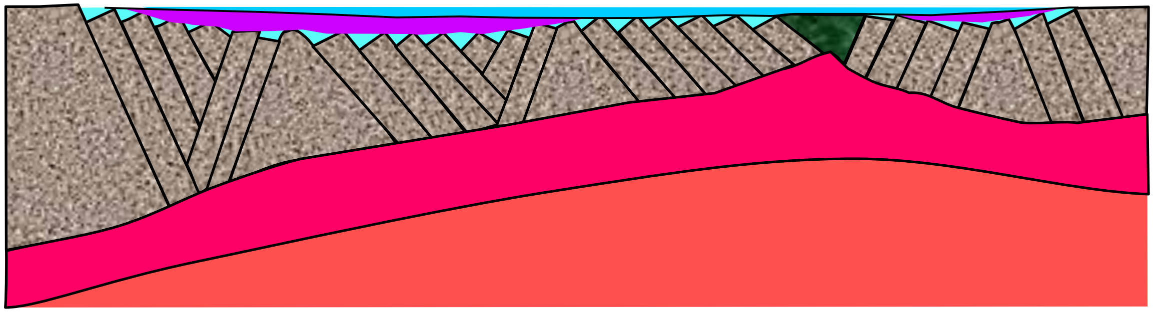
195 mya



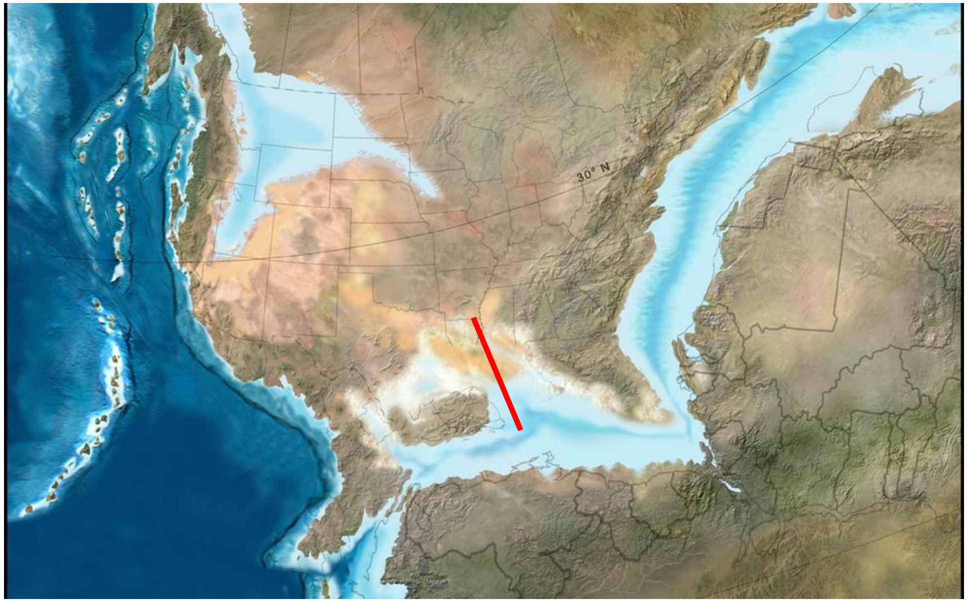


180 mya

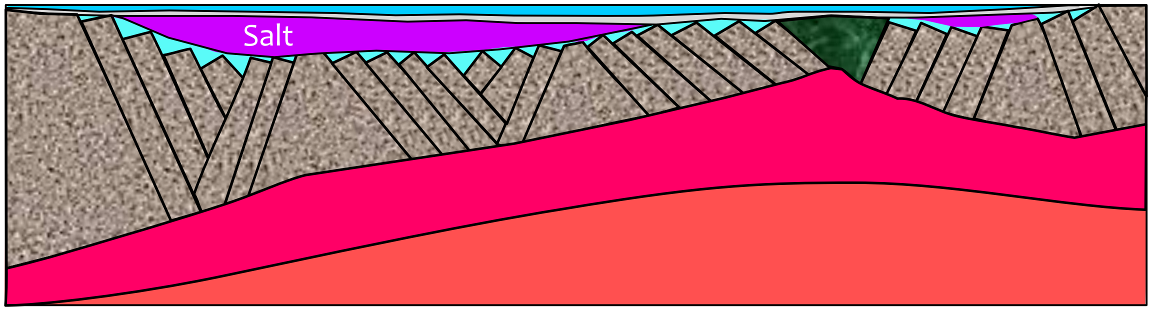




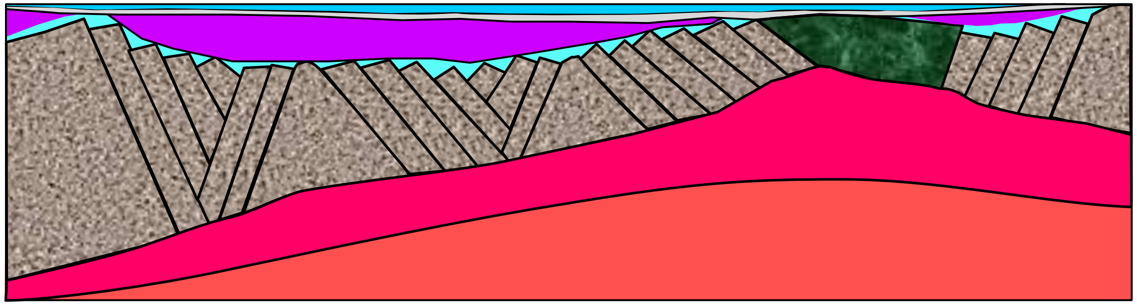
170 mya



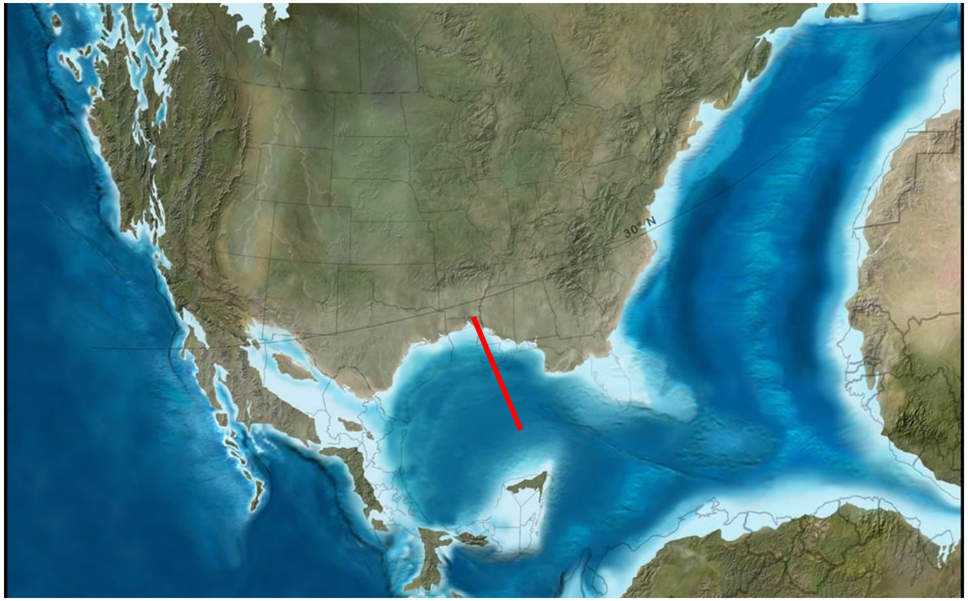
As movement of the plates progressed toward the opening of the Atlantic Ocean and the Gulf of Mexico, there was a period of limited ocean circulation within the basin, and a thick layer of salt formed due to evaporation in the restricted basin – shown in purple

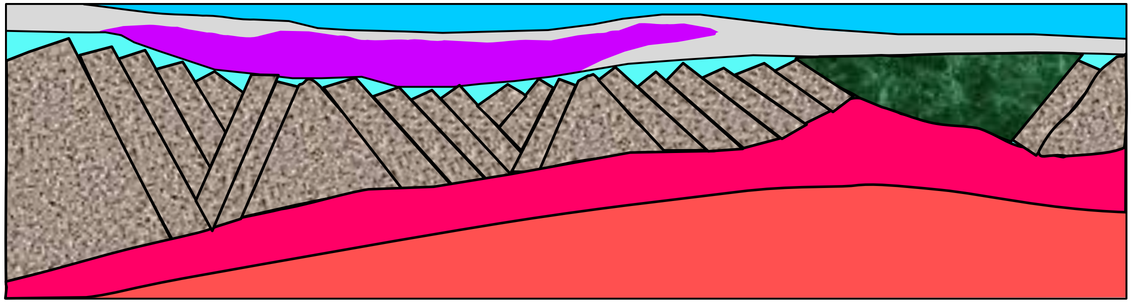


150 mya

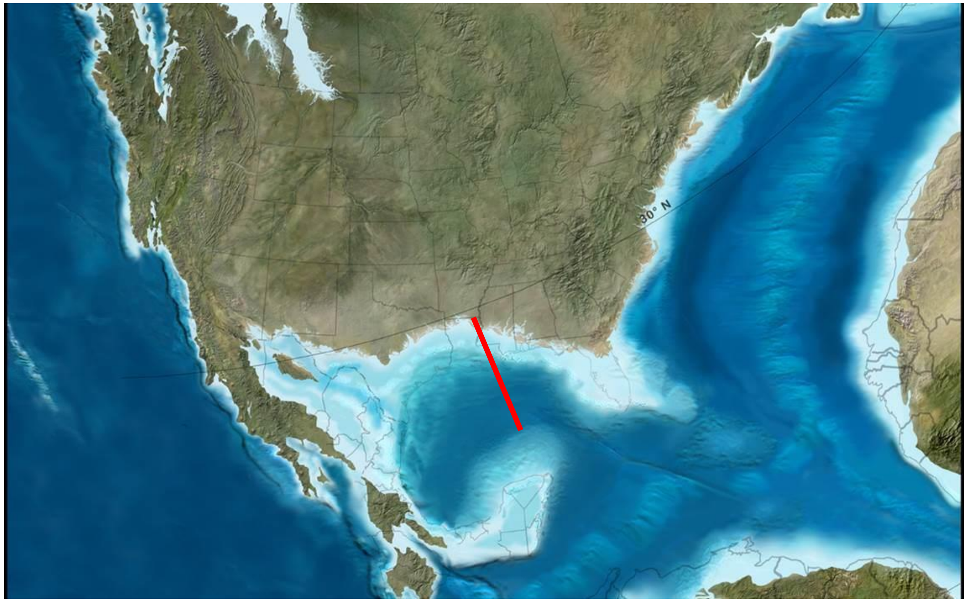


130 mya

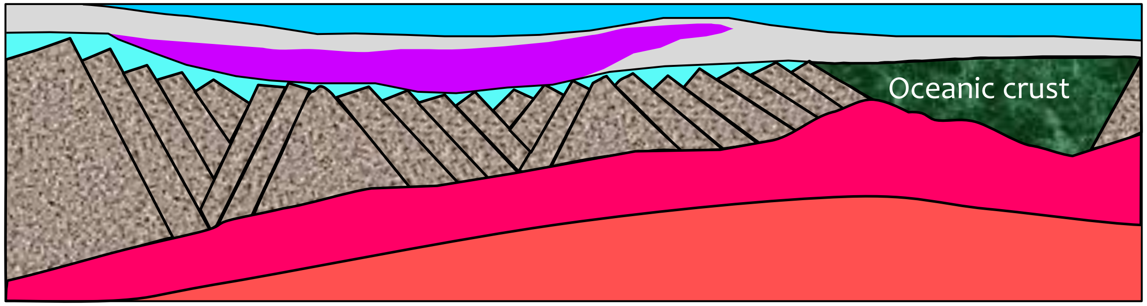




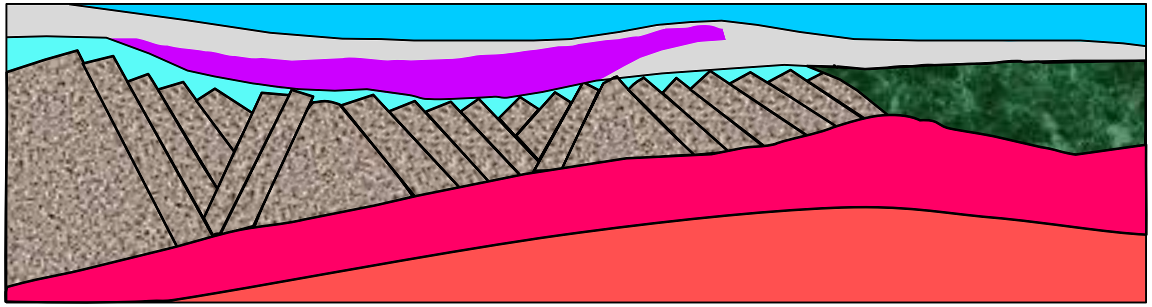
115 mya



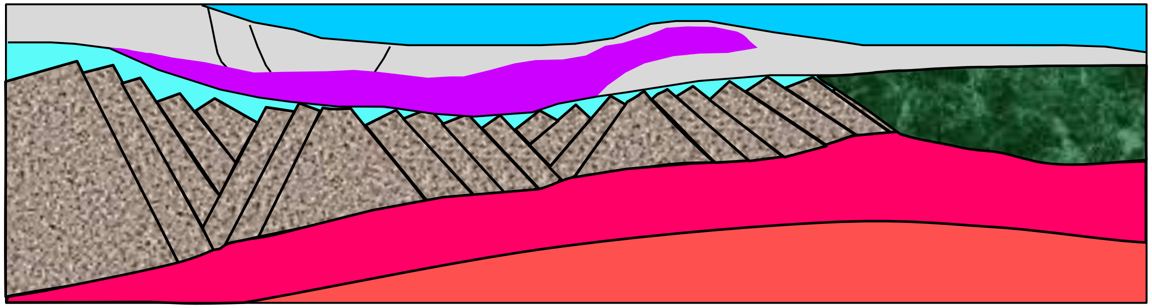
With open ocean circulation mineral sediment accumulation began. It was slow at first without much input from the North American Continent. The granite basement continued to subside throughout this time period, and new oceanic crust began to form in the center of the basin



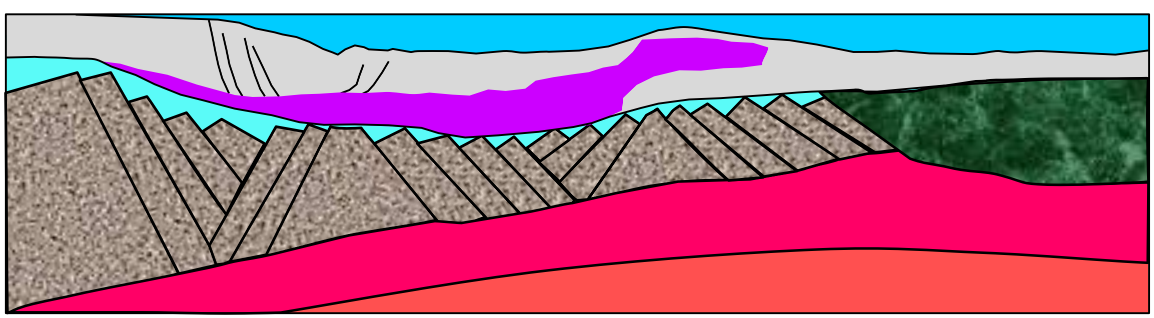
105 mya



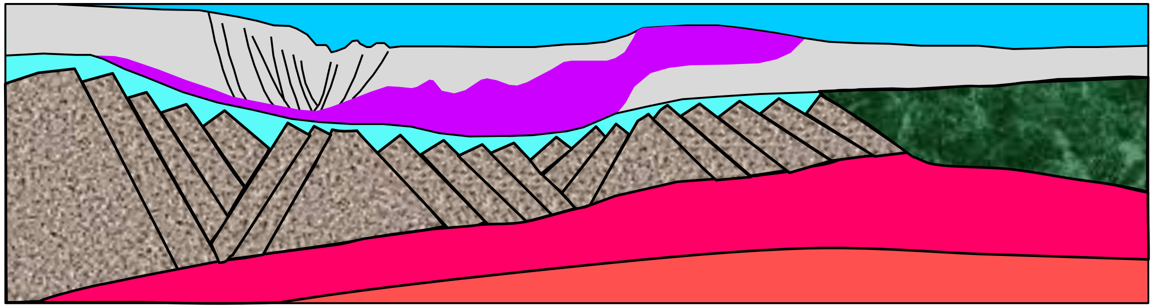
92 mya



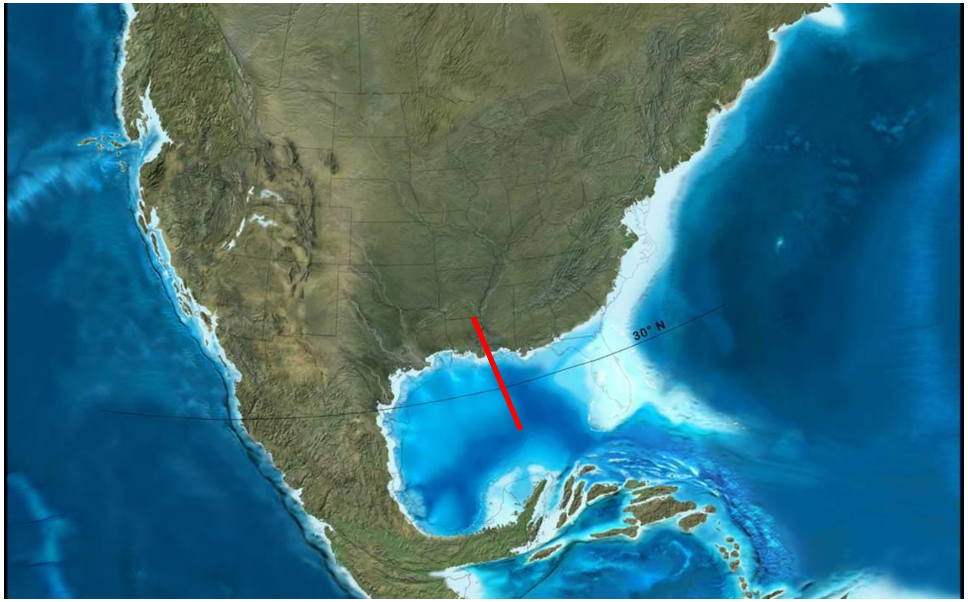
85 mya



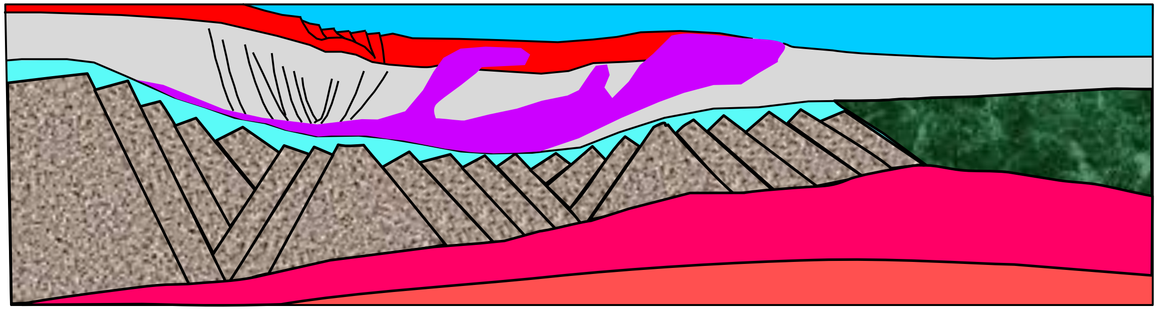
72 mya



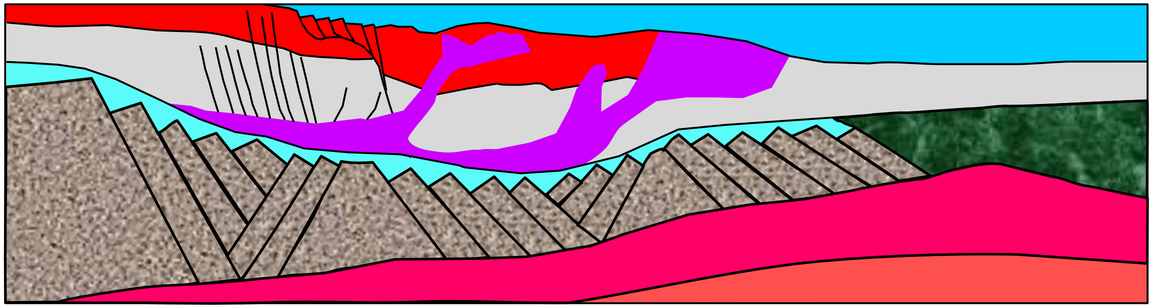
60 mya



The first formation of the Rocky Mountains at about this time brought in the first real influx of mineral sediment from the continent. The Mississippi River drainage basin began to form, but most of the sediments eroded from the Rockies were entering the basin through the Texas river systems.



50 mya



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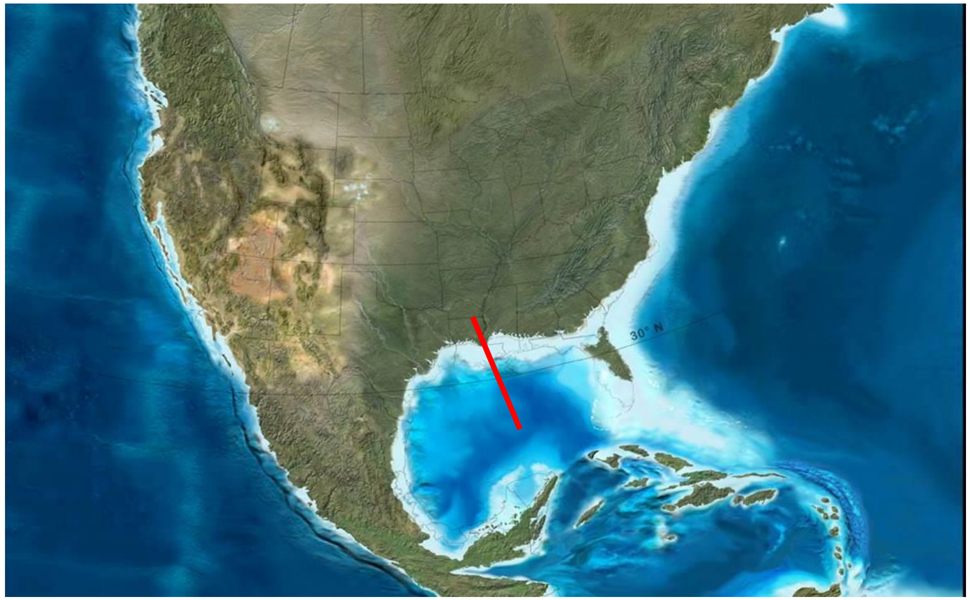
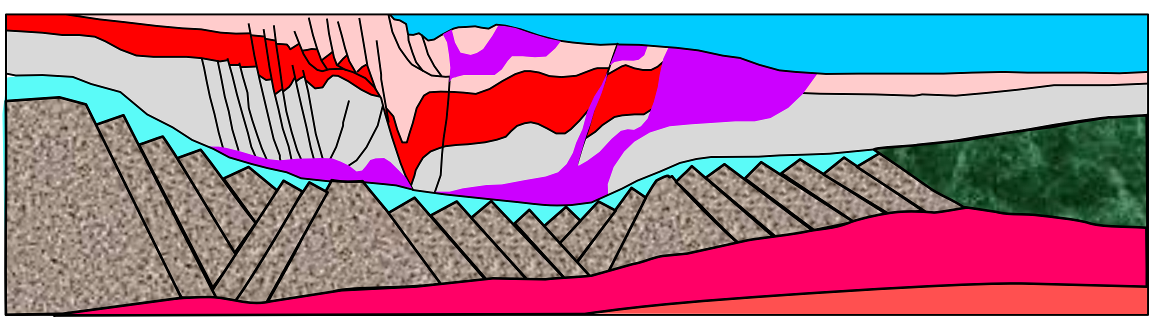
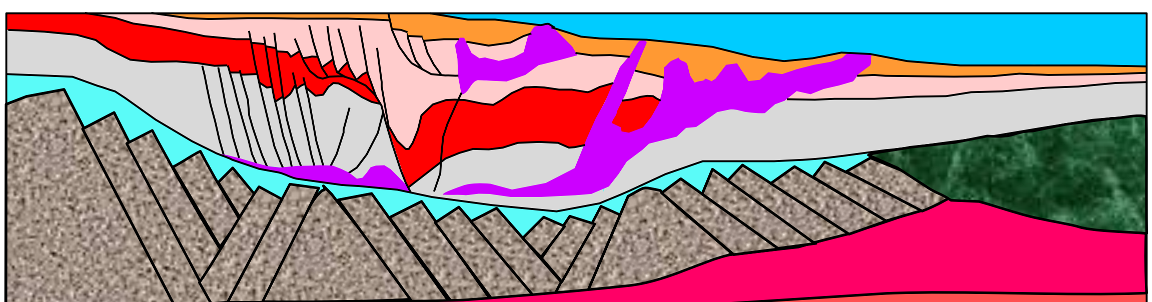




20 mya

By the Miocene Epoch in the Cenozoic Era the Mississippi River drainage basin was fully developed and its delta systems were mostly centered over southern Louisiana. The sand layers deposited by these deltas are now the sites of oil and gas accumulation miles below the surface.



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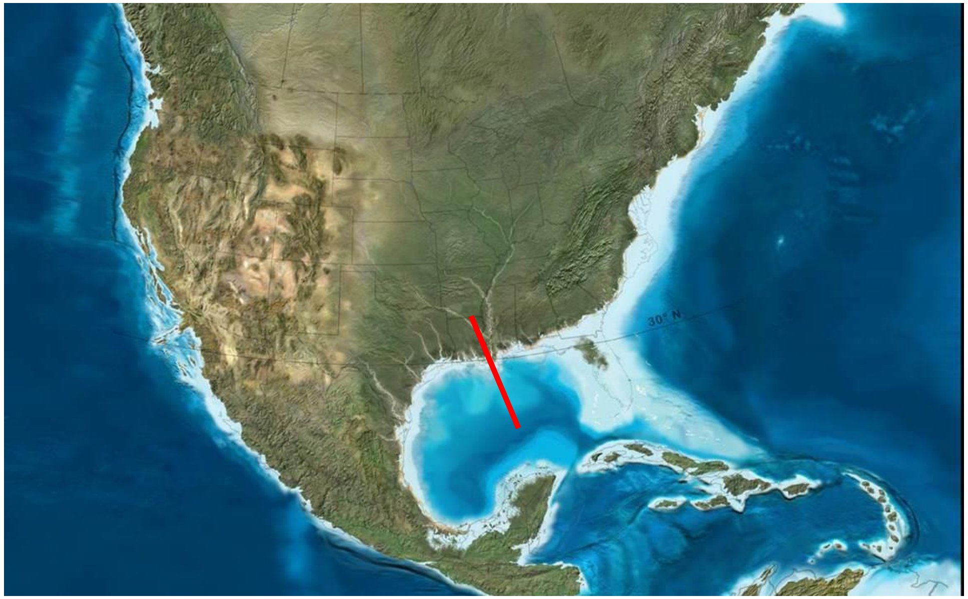

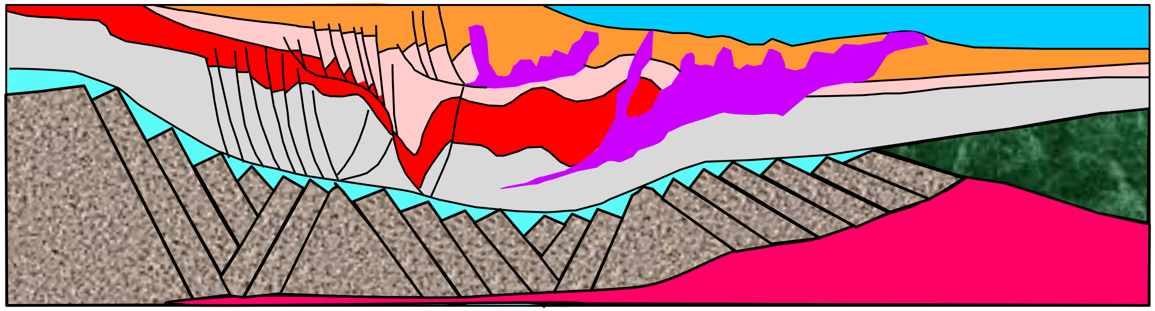

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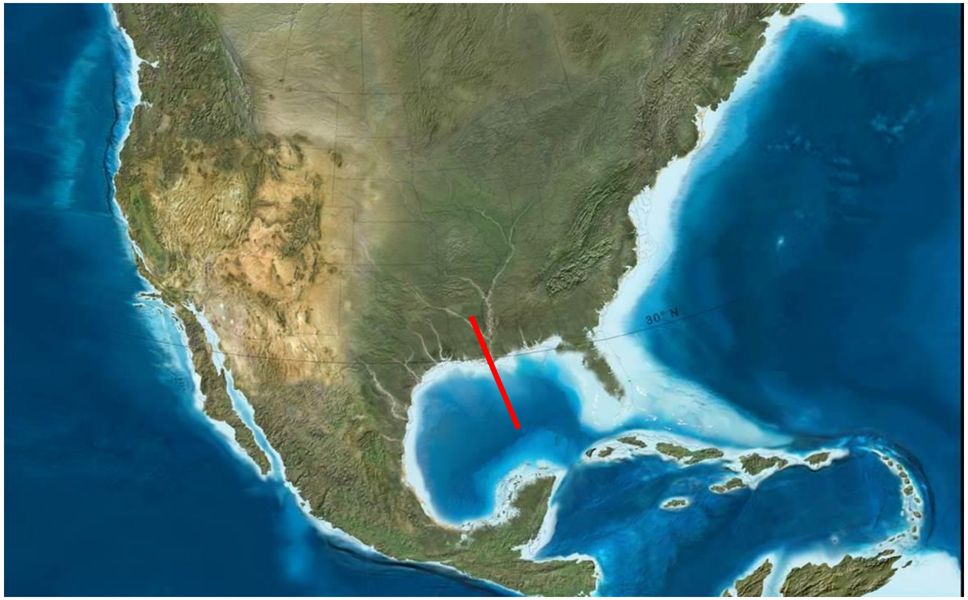
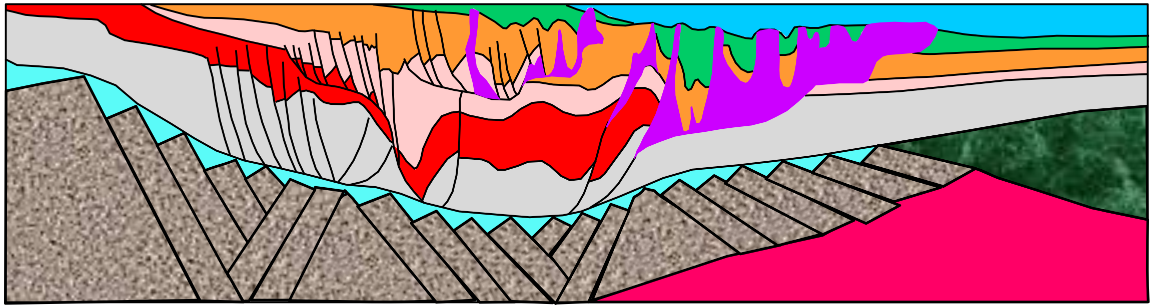
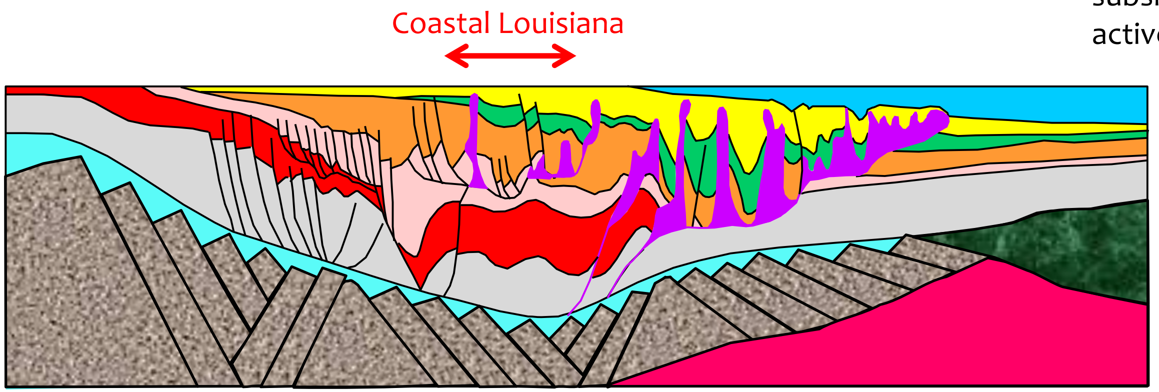




Present

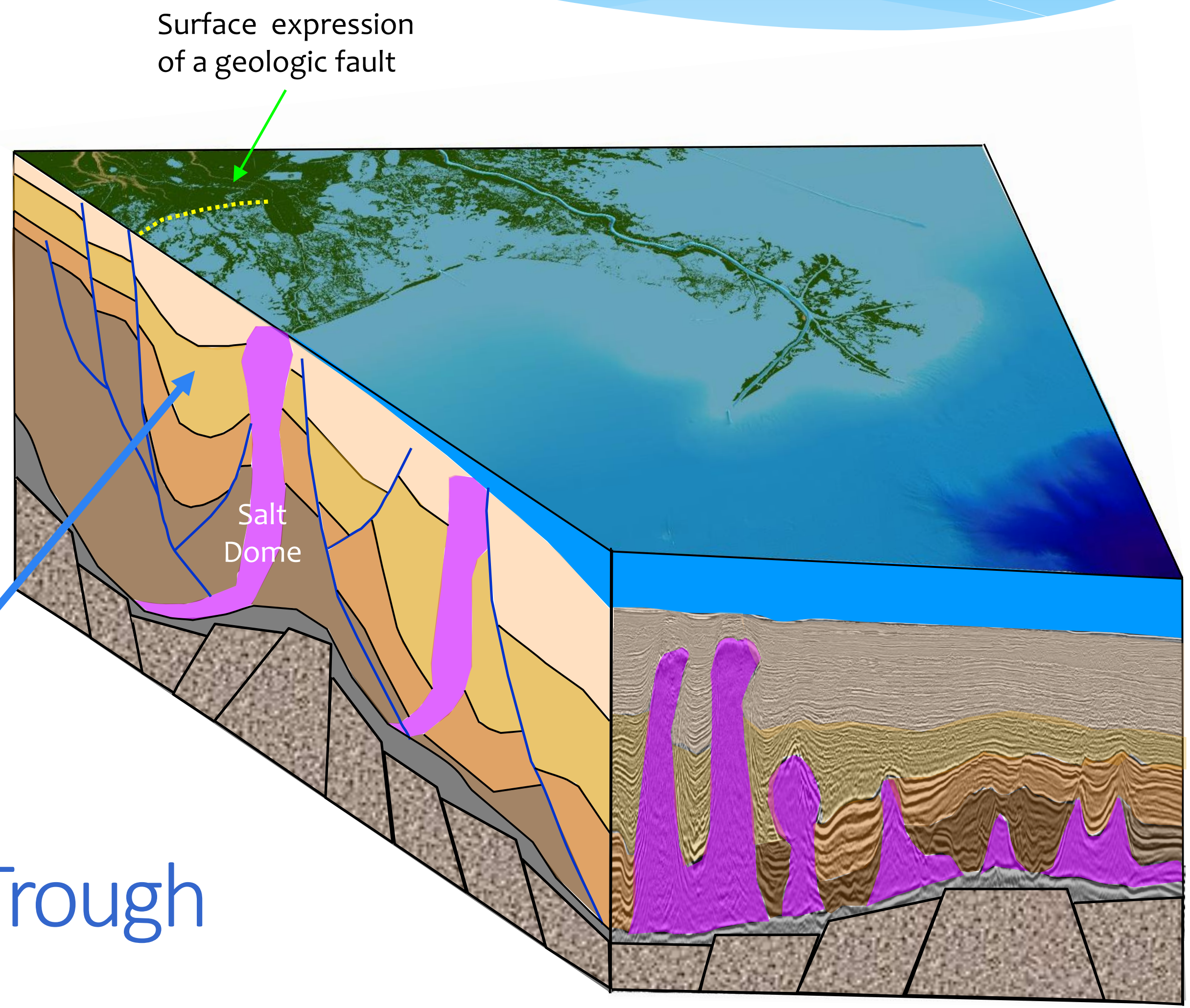
The present day Gulf of Mexico basin was formed by the continuous progression of subsidence that provided the accommodation space for the accumulation of sediments being eroded form the continent and carried by the river system.

The coastal wetlands of Louisiana are the most recent deposits of the river, and they are being subjected to the same processes of subsidence that have been active for millions of years.



A more detailed view of the subsurface of coastal Louisiana shows the geologic feature called the Terrebonne Trough that underlies the coast. The original salt layer has been squeezed up into domes, and the sedimentary layers are broken by geologic faults that are primary mechanisms of subsidence.

Recent studies have indicated that many of these faults extend to the current land surface and some have obvious expressions at the surface. One example is shown as a dashed yellow line.



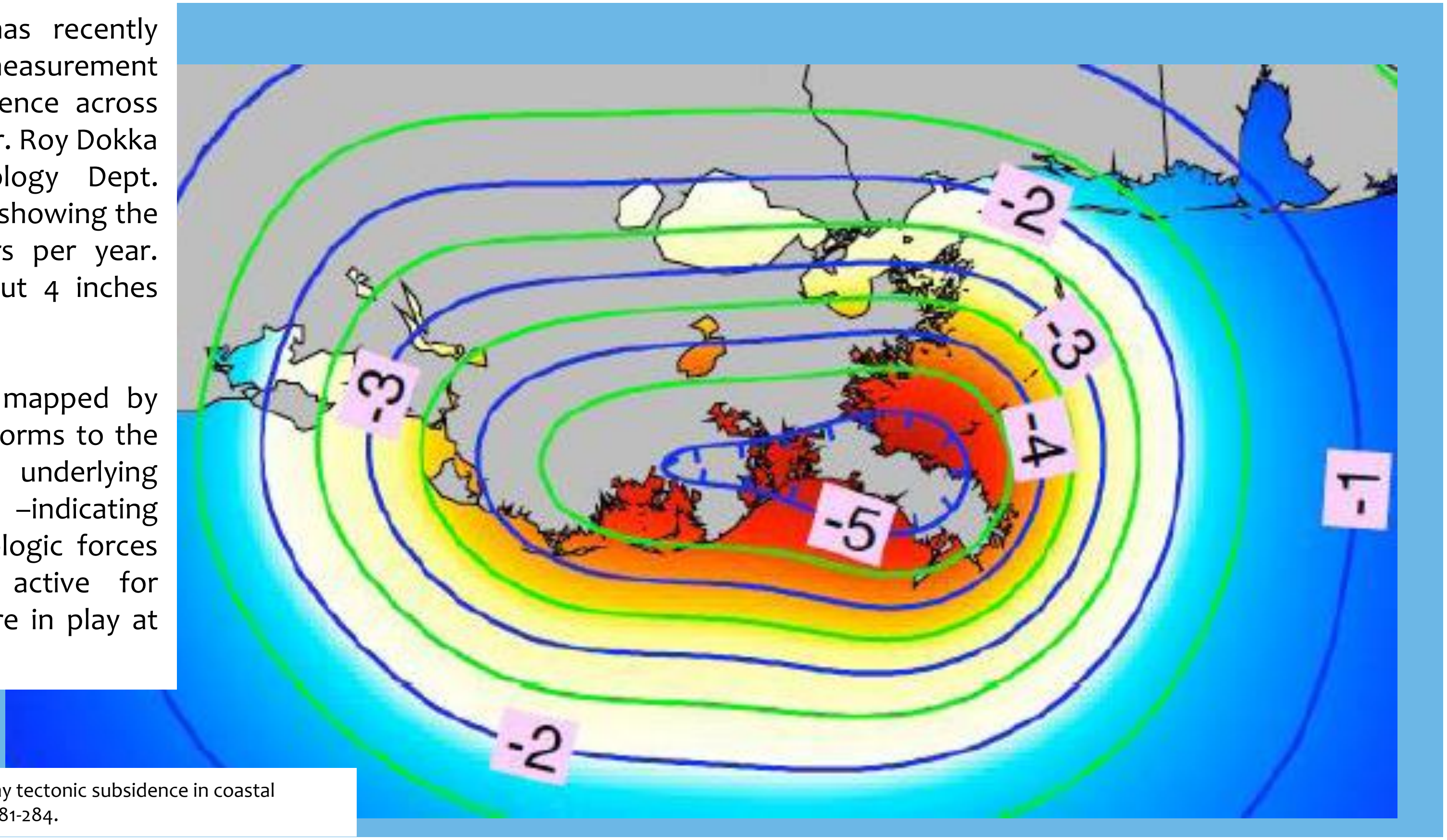
The Terrebonne Trough

"Background" Subsidence

measured in mm/year today

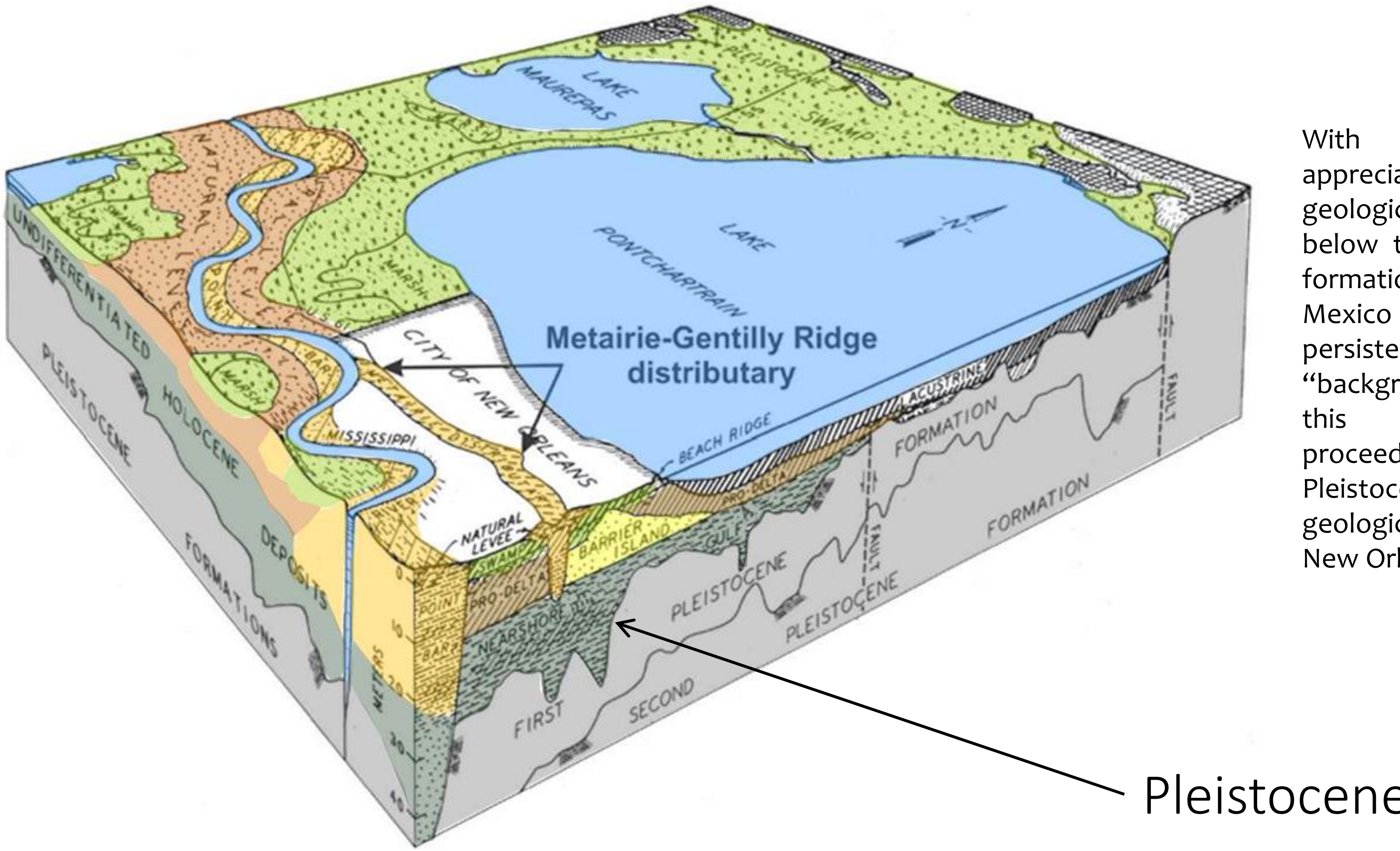
GPS technology has recently allowed for the measurement of rates of subsidence across the land surface. Dr. Roy Dokka of the LSU Geology Dept. published this map showing the rates in millimeters per year. One mm/yr is about 4 inches per century.

The configuration mapped by Dokka exactly conforms to the shape of the underlying Terrebonne Trough –indicating that the same geologic forces that have been active for millions of years are in play at the surface today.



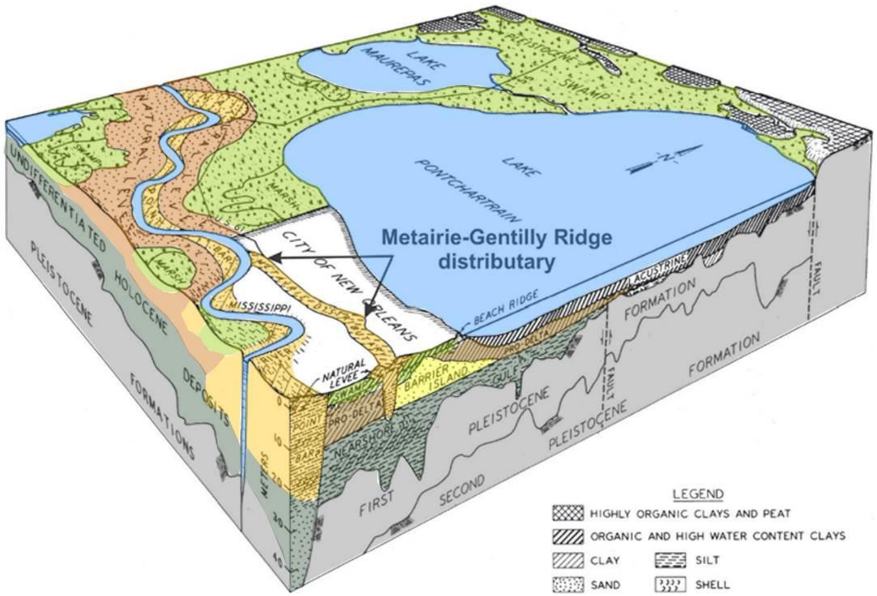
Dokka, R.K., 2006, Modern-day tectonic subsidence in coastal Louisiana, Geology, v. 34, p. 281-284.

New Orleans
below the surface



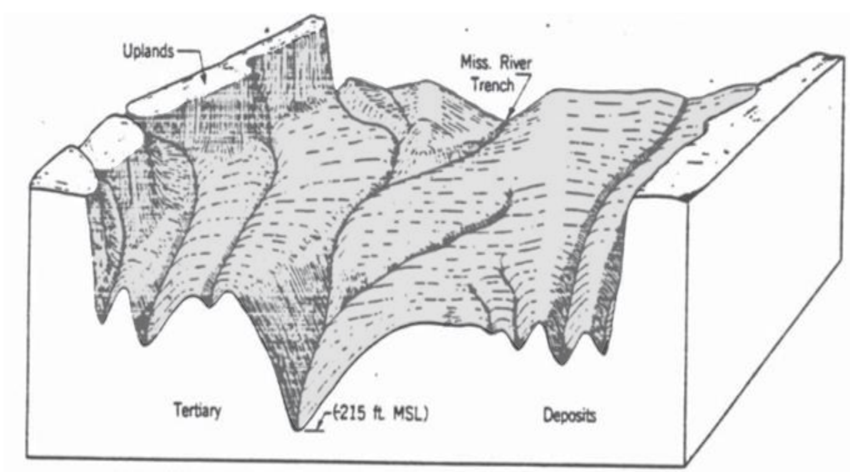
With the foregoing appreciation that the real geological basement is miles below the surface, and the formation of the Gulf of Mexico Basin has imposed a persistent measure of "background subsidence", this presentation can proceed with treating the Pleistocene surface as geological basement for the New Orleans area.

Pleistocene Surface

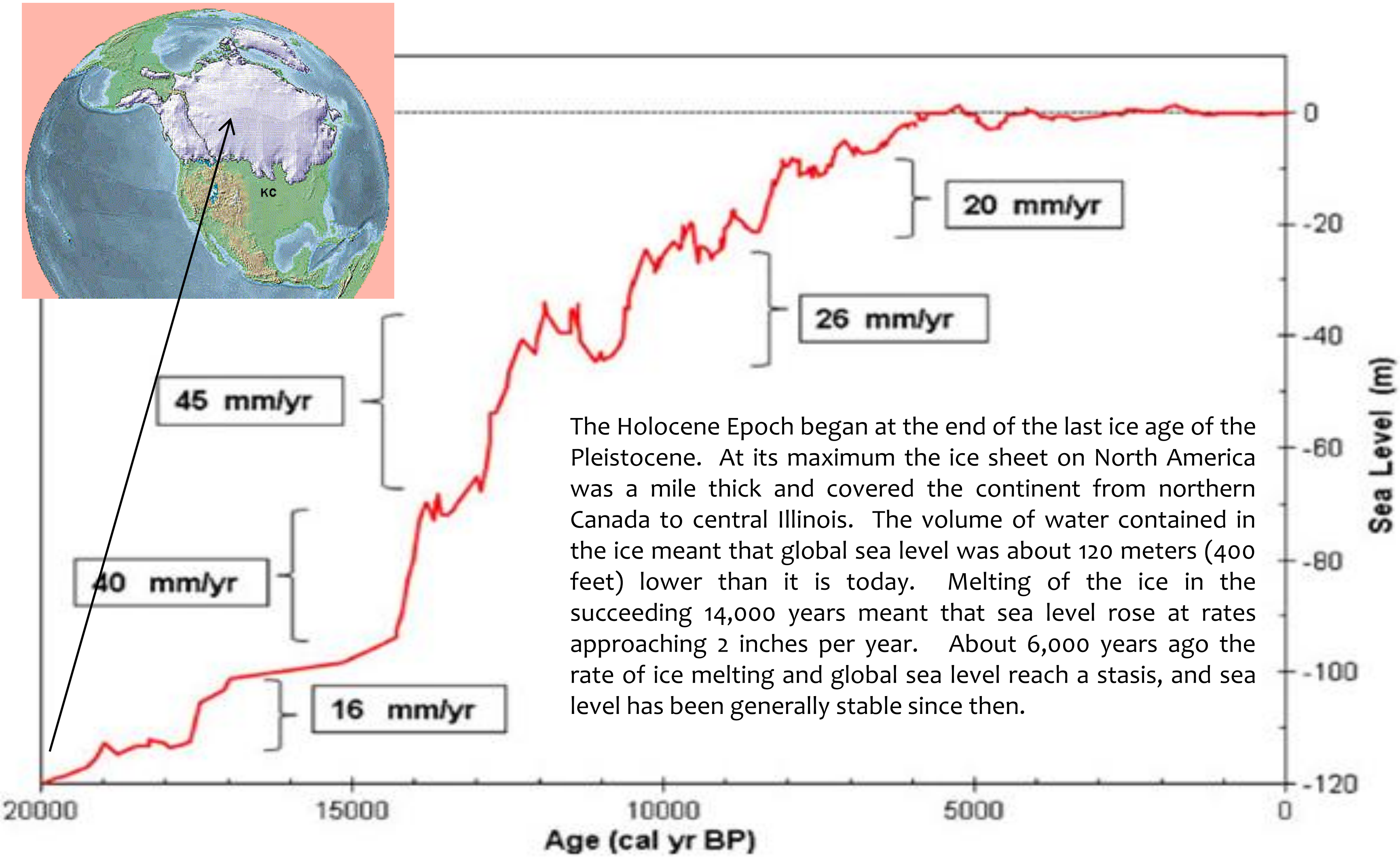


If all of the sediments that currently overlie the Pleistocene surface were stripped away, the surface would be revealed as an erosional landscape with topography closer to that of northern Louisiana than the coastal plain.

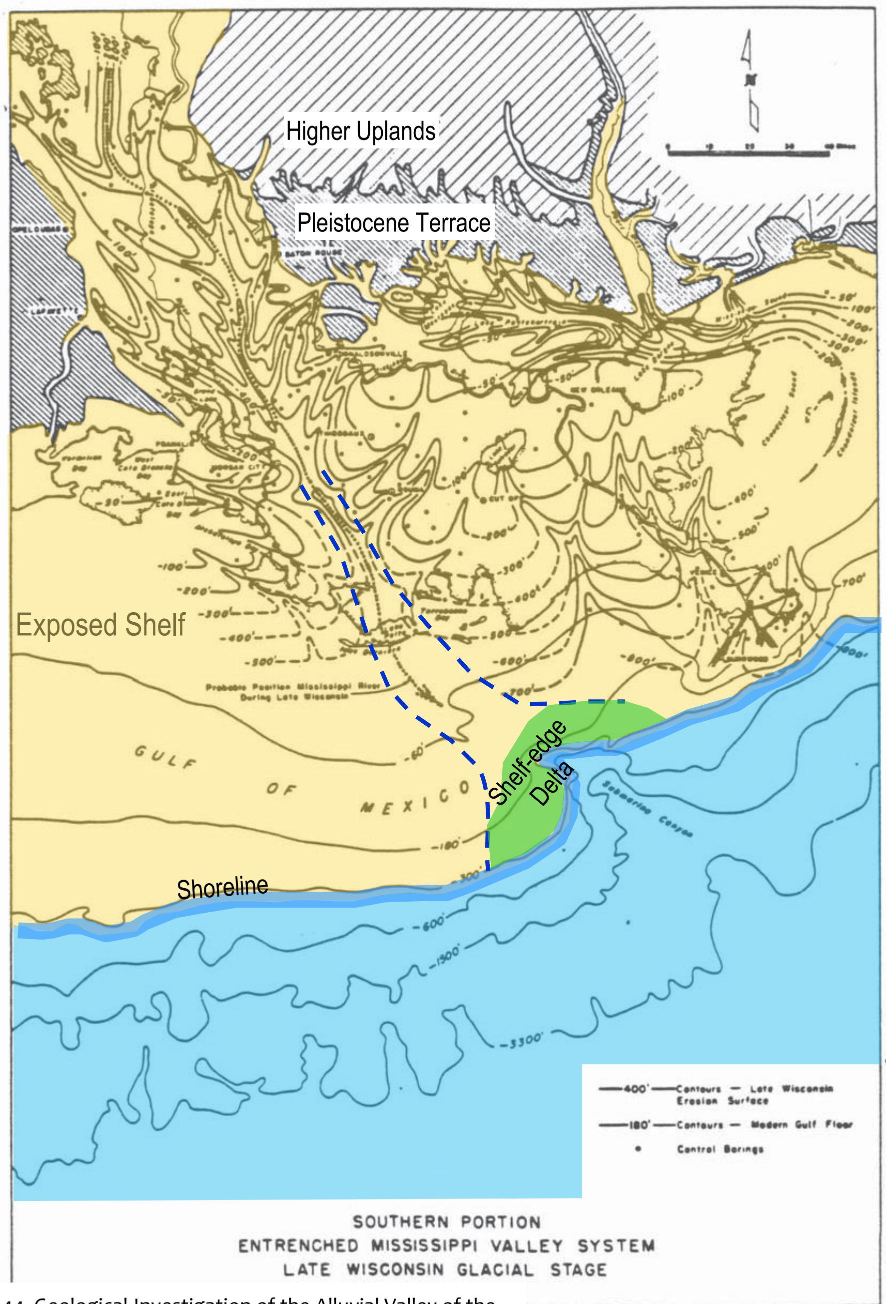
This was in fact the surface topography of the New Orleans area about 20,000 years ago.



Holocene Sea Level

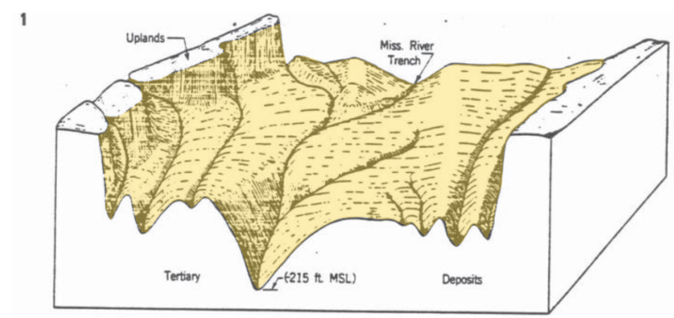


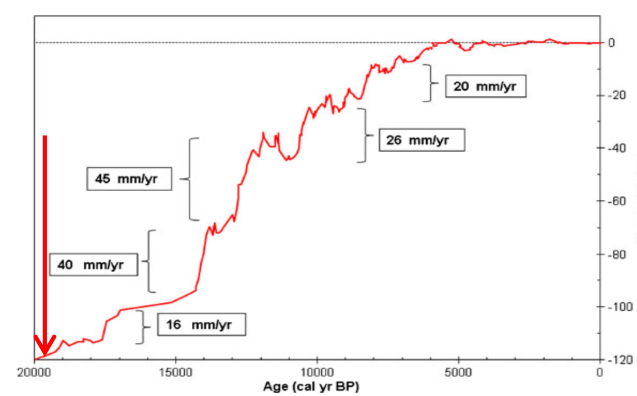
The Holocene Epoch began at the end of the last ice age of the Pleistocene. At its maximum the ice sheet on North America was a mile thick and covered the continent from northern Canada to central Illinois. The volume of water contained in the ice meant that global sea level was about 120 meters (400 feet) lower than it is today. Melting of the ice in the succeeding 14,000 years meant that sea level rose at rates approaching 2 inches per year. About 6,000 years ago the rate of ice melting and global sea level reach a stasis, and sea level has been generally stable since then.

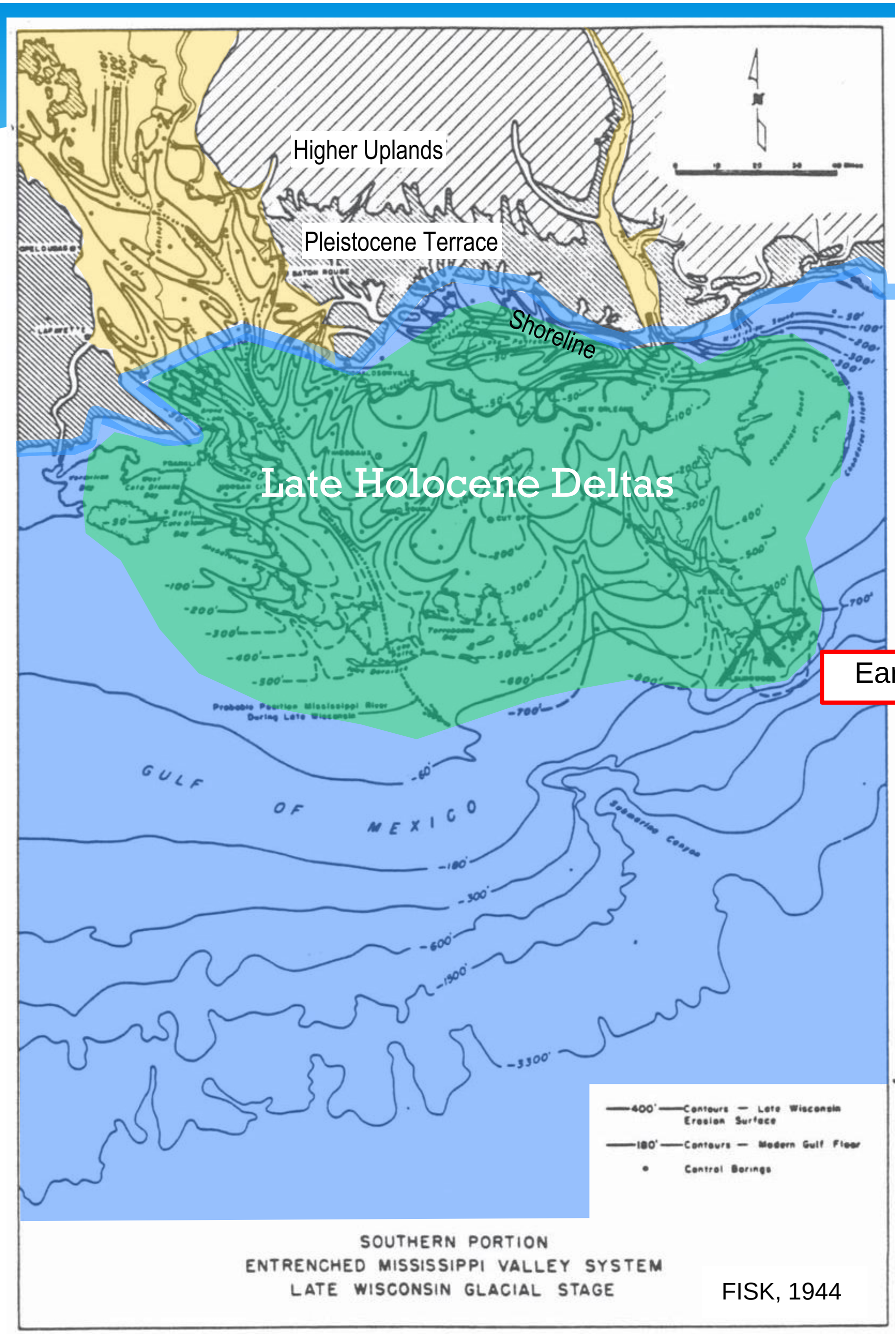


Fisk, H.N., 1944, Geological Investigation of the Alluvial Valley of the Lower Mississippi River, U.S.A.C.E., 170 p.

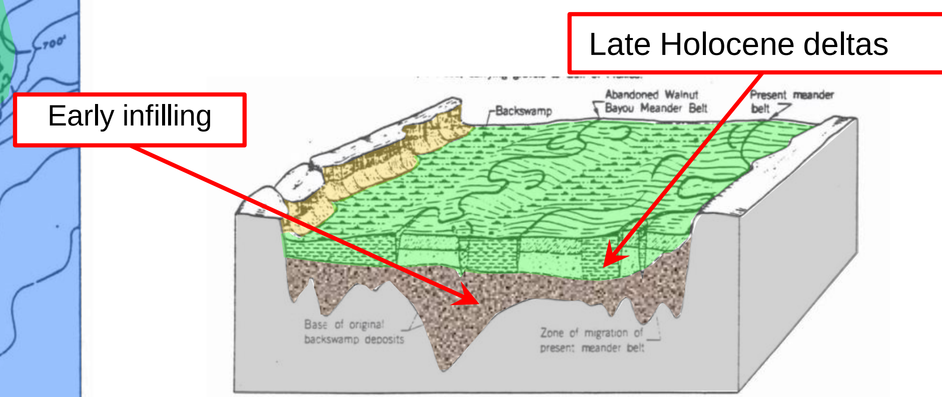
A 400-foot drop in sea level meant that the Gulf of Mexico shoreline was at the continental shelf edge. All of southern Louisiana was covered by the firm clay sediments of the Pleistocene, and it was cut by ravines up to 200 feet deep.

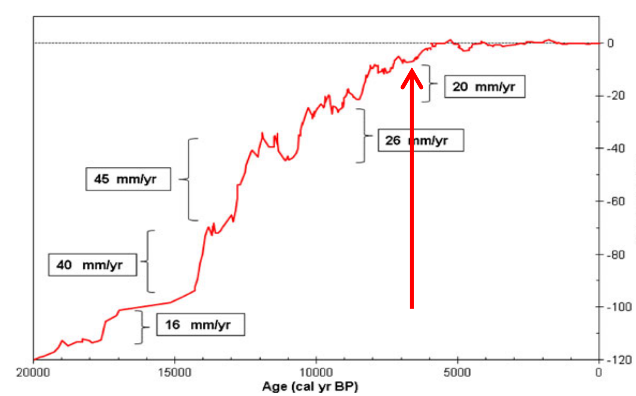






As sea level rose, the Pleistocene surface was submerged and its topography filled in with sediment. The rate of sea level rise until 6,000 years ago prevented the preservation of deltas of that time as recognizable in the sedimentary record. During sea level stasis the delta deposits have been preserved in great detail.

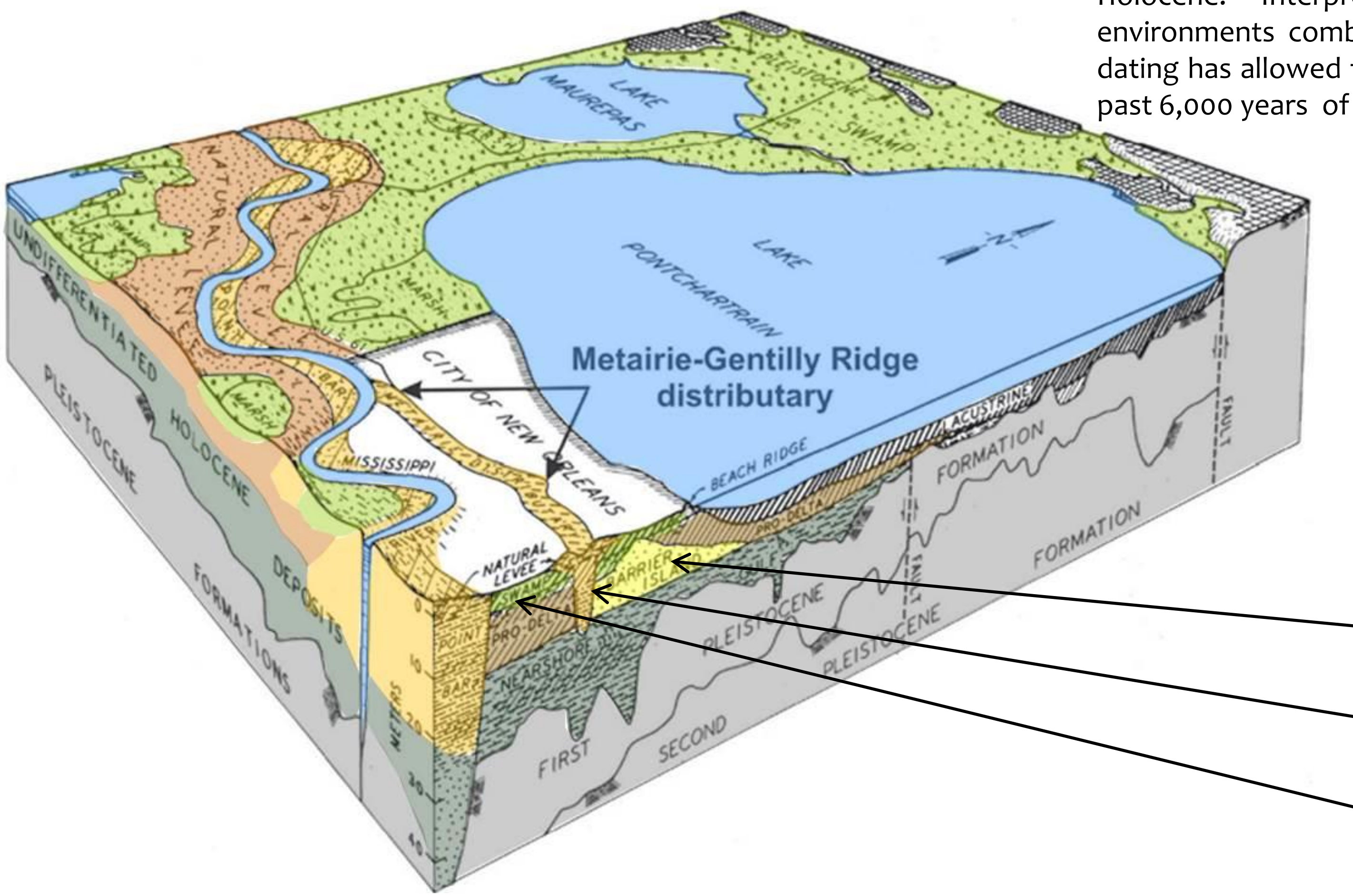




New Orleans

below the surface

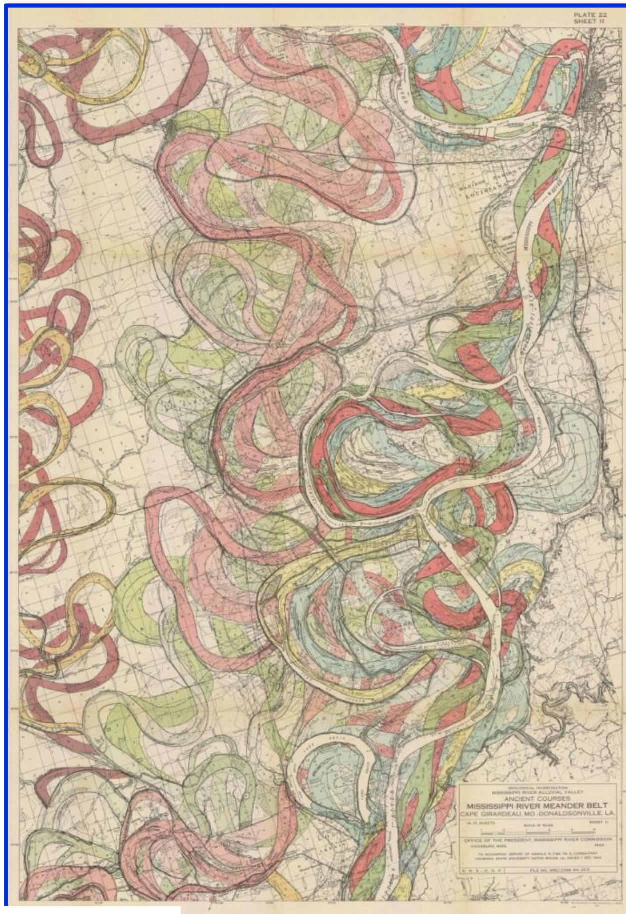
The barrier island, river channel and peat deposits below New Orleans are a part of the well-preserved sedimentary record of the late Holocene. Interpretation of the sedimentary environments combined with radiocarbon age-dating has allowed for the reconstruction of the past 6,000 years of the New Orleans area.

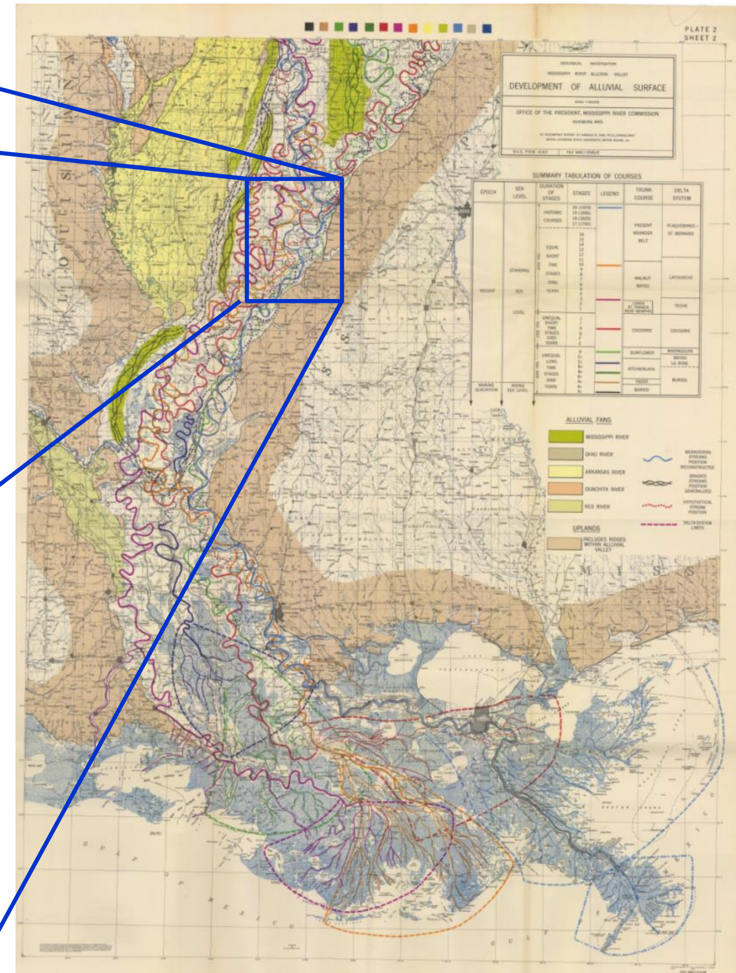


Landscape in Flux

Mississippi River over time

The seminal work of Harold Fisk of the LSU Geology Dept. in the 1940's provided the first indications of the dynamic history of the Mississippi River system and its coastal plain. Fisk used aerial photography to interpret the surface expressions of paleo-river channels – showing that the river meandered back and forth across its floodplain before being entrained to one channel in the early 20th century. Fisk also made the first attempt to define the historical deltas of the late Holocene.





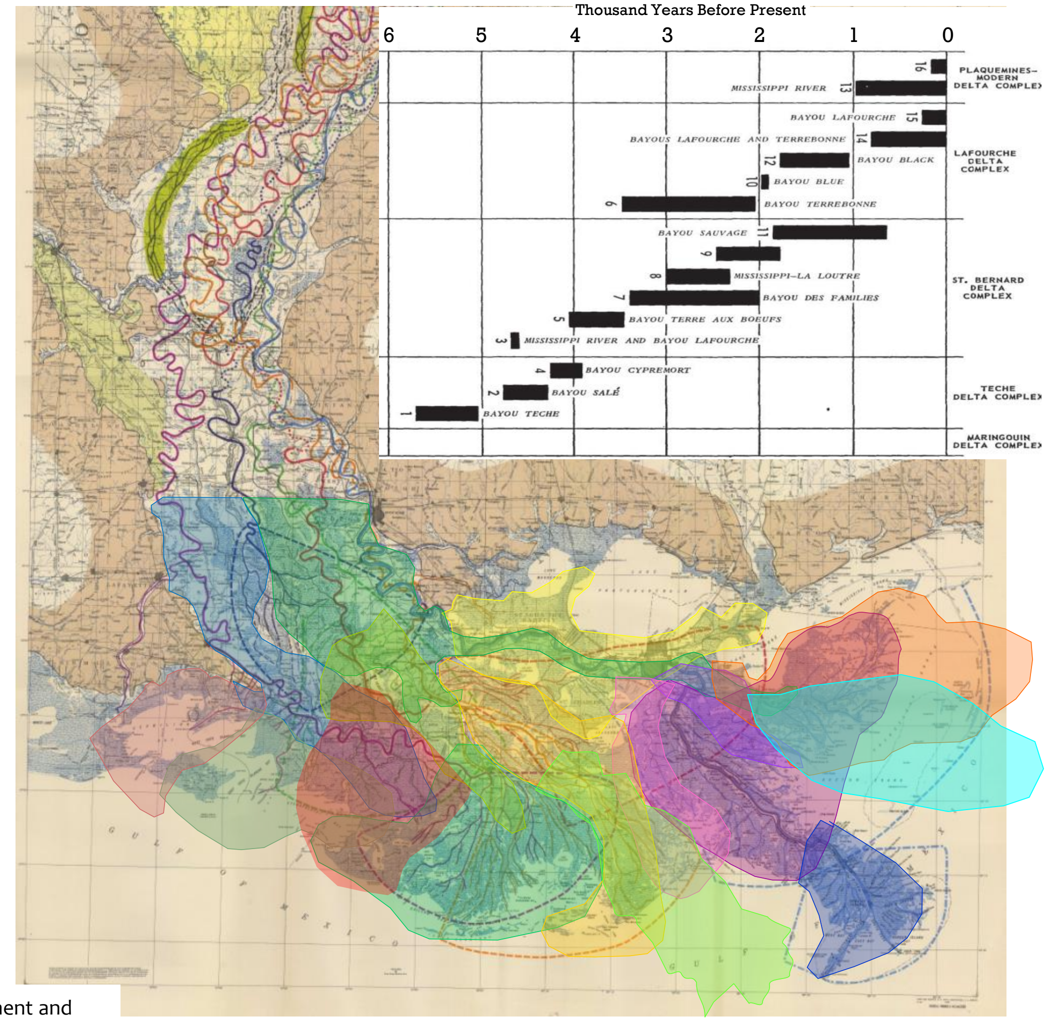
Fisk, H.N., 1944, Geological Investigation of the Alluvial Valley of the Lower Mississippi River, U.S.A.C.E., 170 p.

Building the Coastal Wetlands

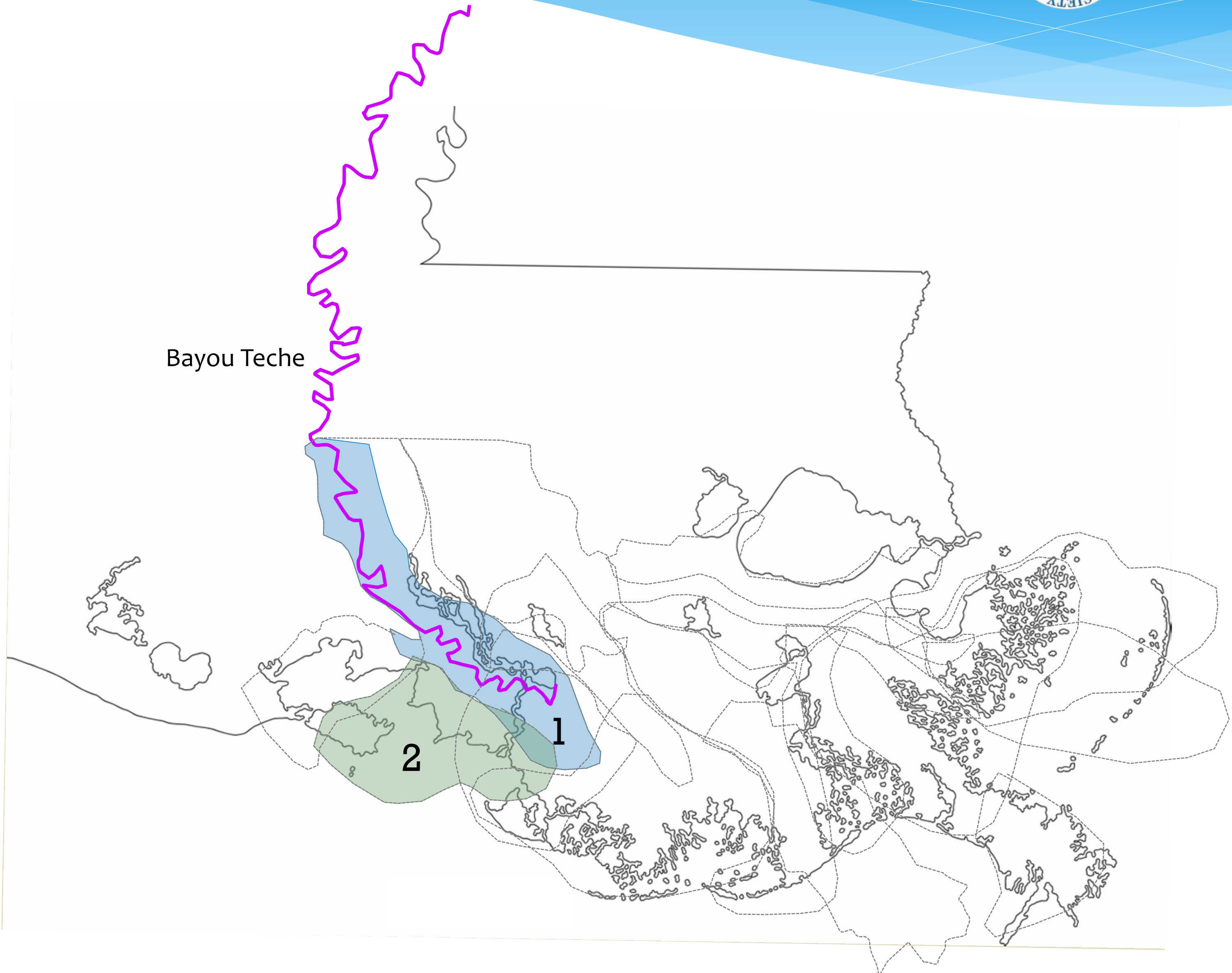
David Frazier of the Exxon Research Lab used hundreds of cores and borings of the shallow subsurface to expand on Fisk's initial work. Frazier identified 16 historical deltas, shown in colored overlay on Fisk's map. The bar chart shows Frazier's interpretation of the lifespan of each delta – about 700 years on average.

The succeeding set of slides will show the progression of channel-switching and delta development worked out by Frazier. Most of the major historical channels of the Mississippi River are represented by present-day bayous in the coastal plain.

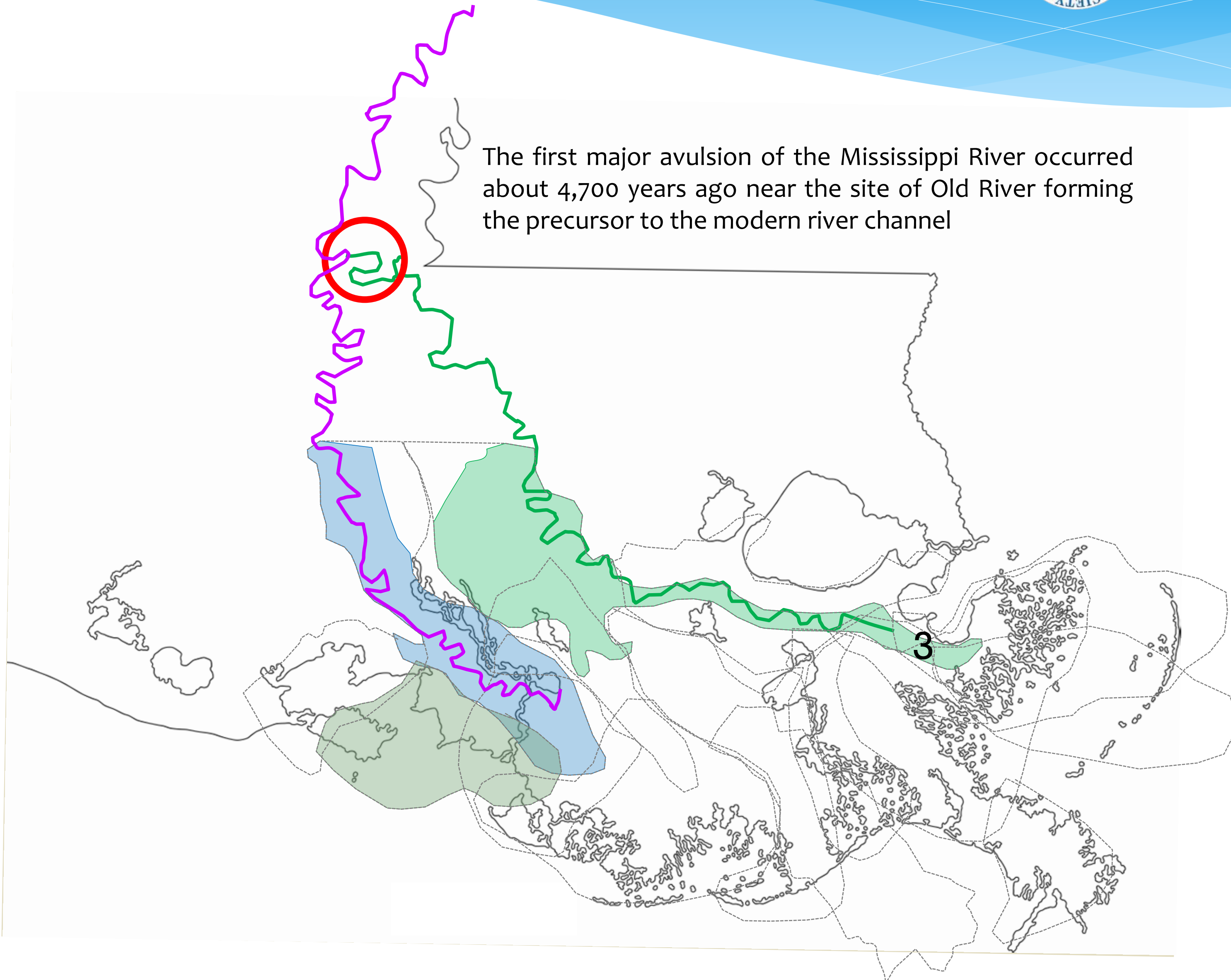
The coastal wetlands were built up during this period by the constant switching back and forth (or avulsing) of the river delta. Major "avulsion nodes" are noted as red circles.

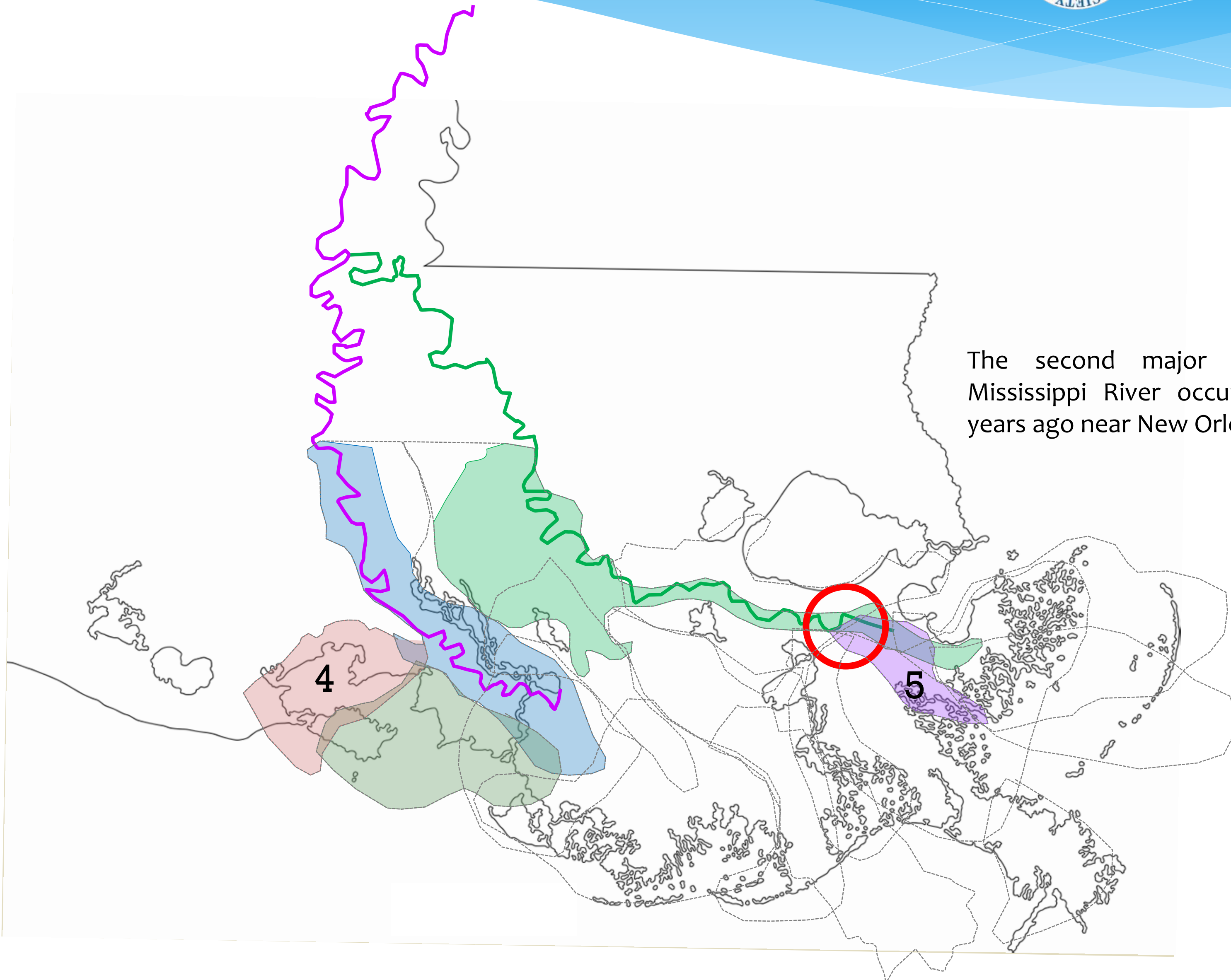


Frazier, D.E., 1967, Recent deltaic deposits of the Mississippi River: their development and chronology, Trans. G.C.A.G.S., v. 17, p. 287-315

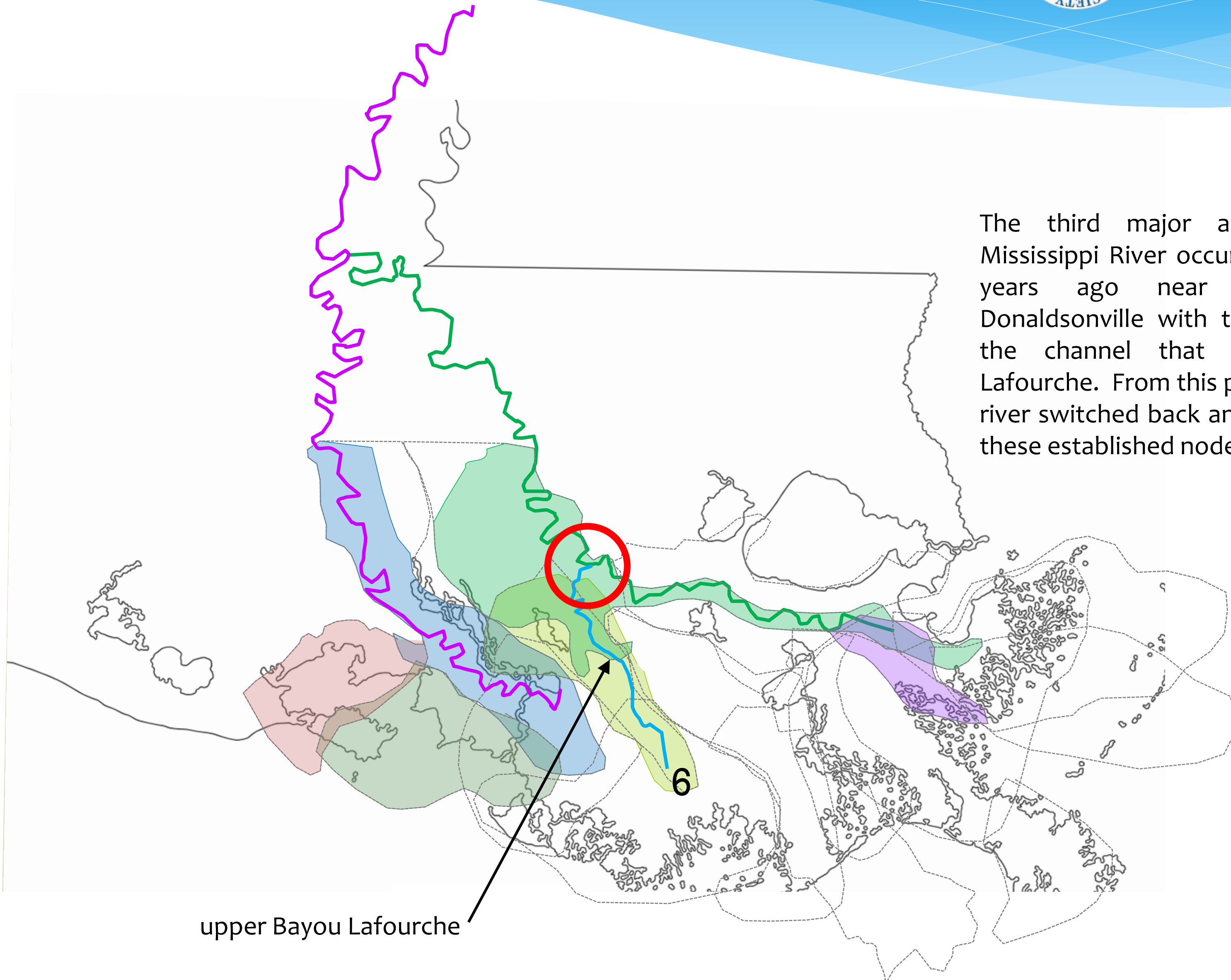

Bayou Teche
1
2

The first major avulsion of the Mississippi River occurred about 4,700 years ago near the site of Old River forming the precursor to the modern river channel

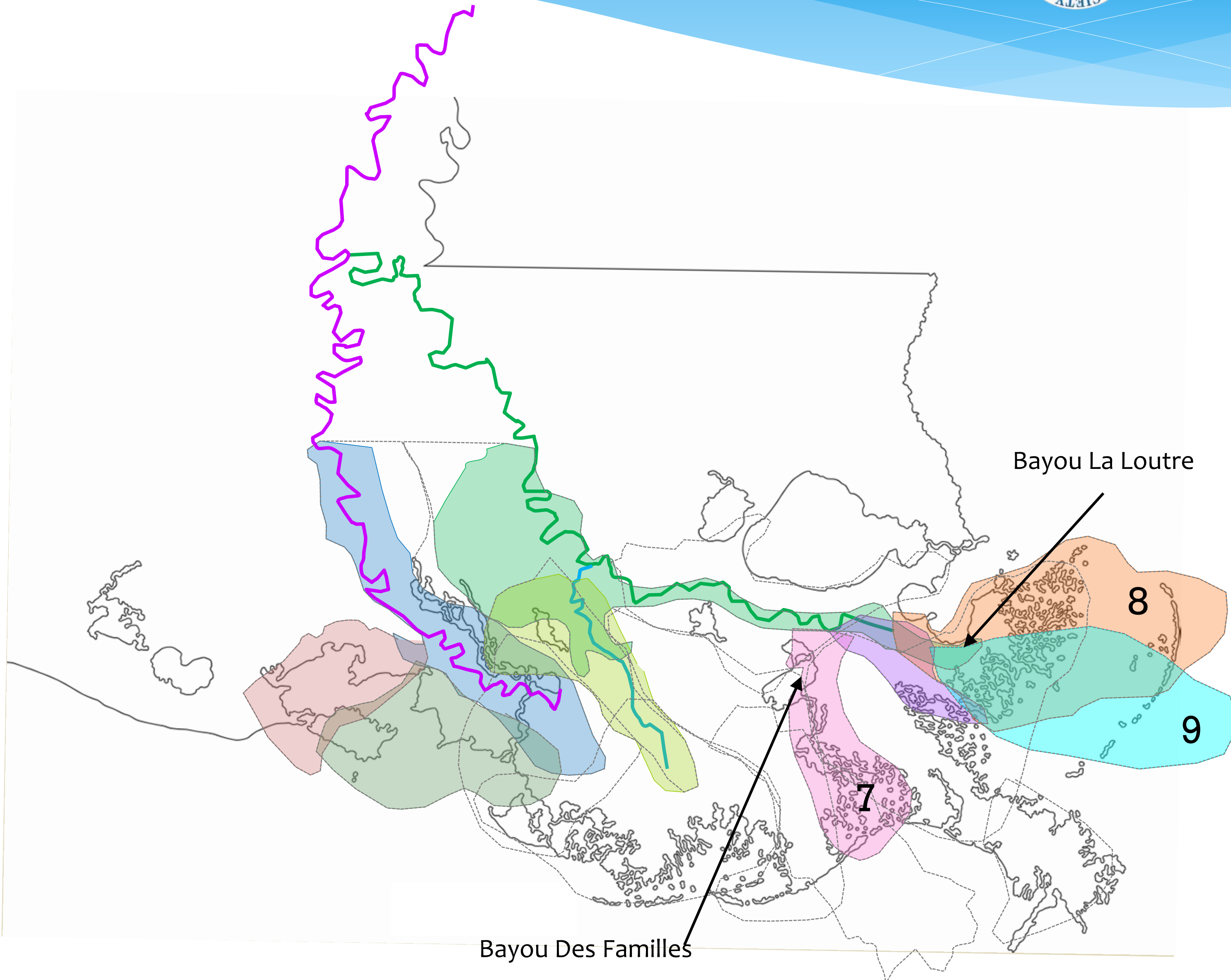




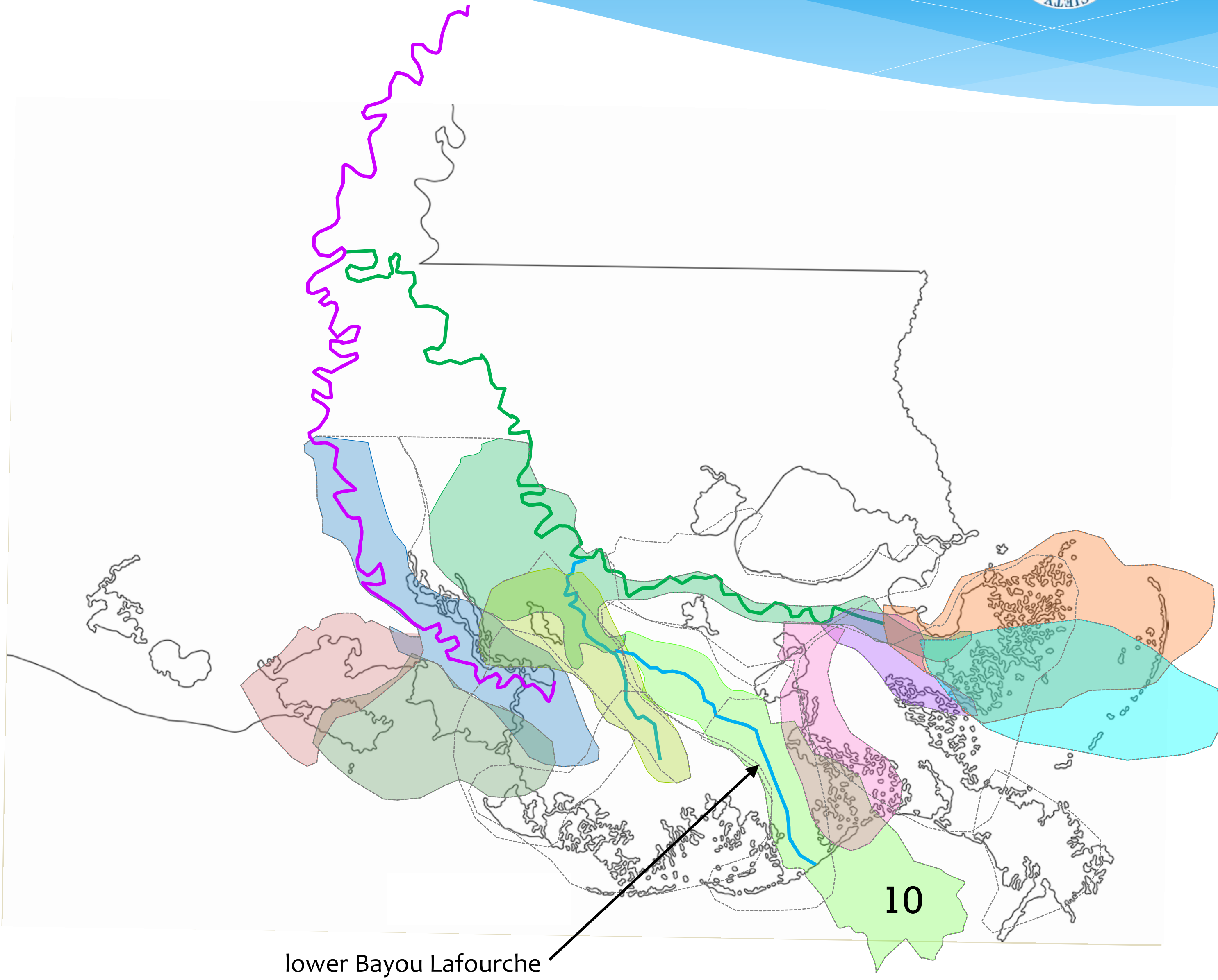
The second major avulsion of the Mississippi River occurred about 4,000 years ago near New Orleans

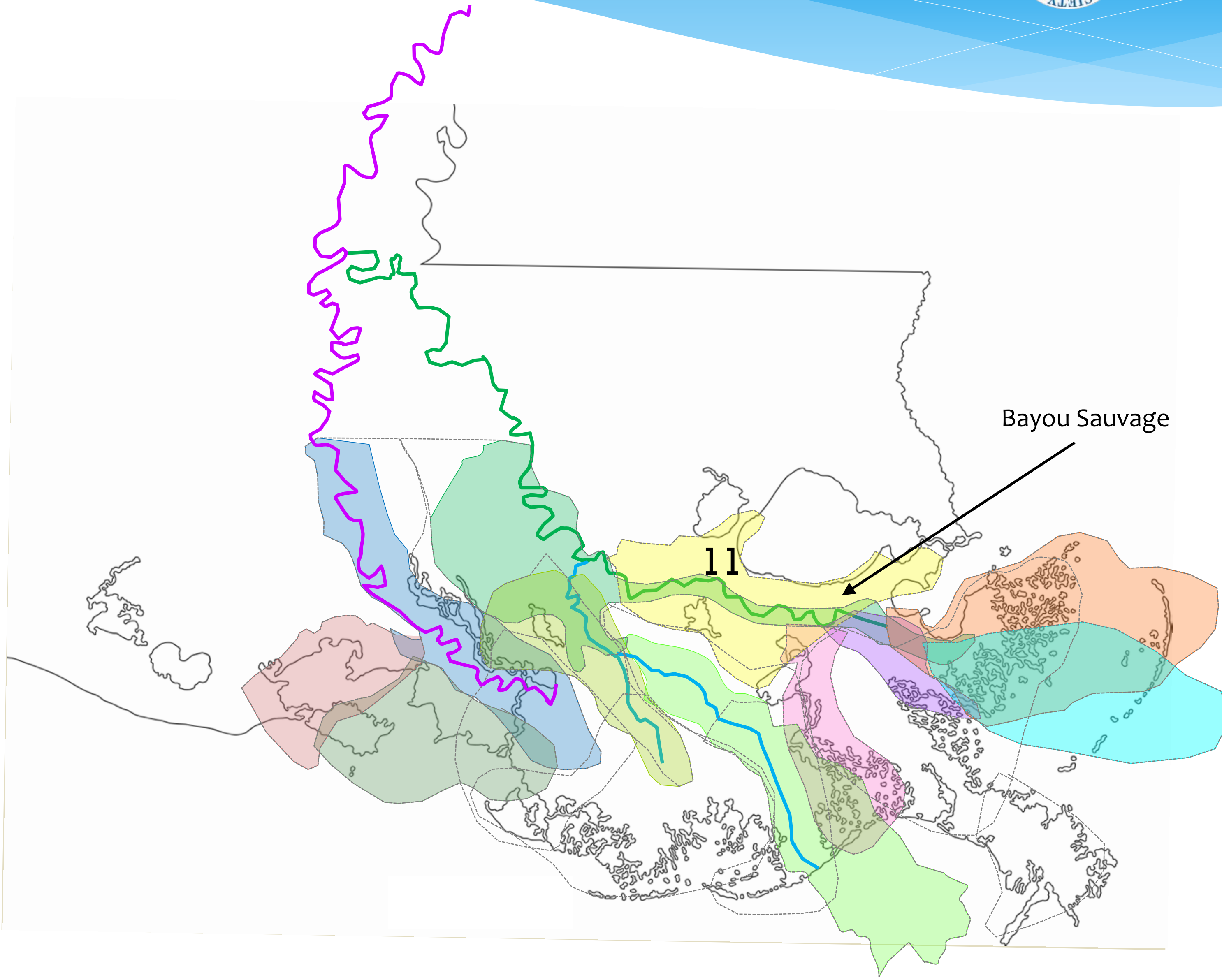


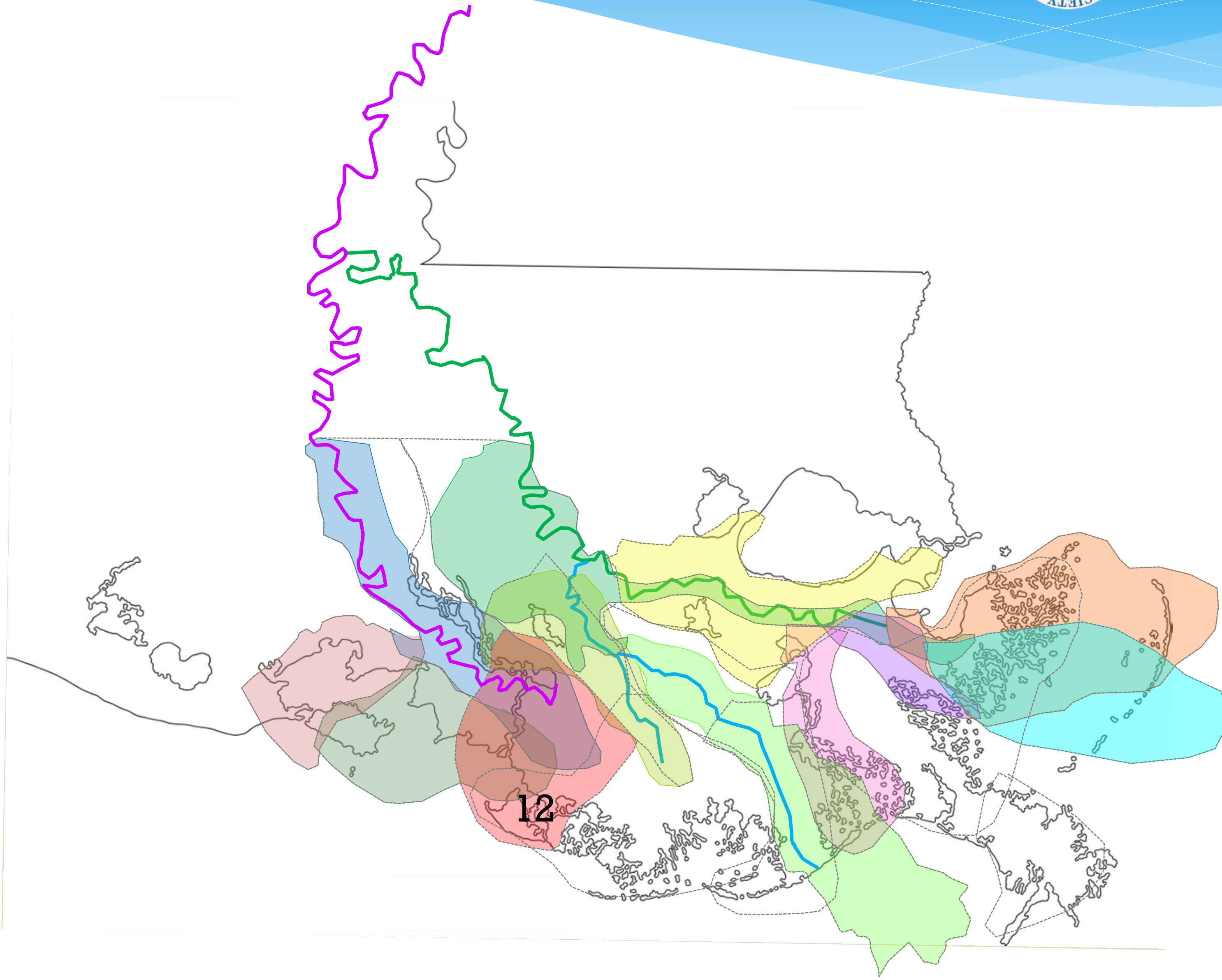
The third major avulsion of the Mississippi River occurred about 3,500 years ago near the site of Donaldsonville with the formation of the channel that is now Bayou Lafourche. From this point forward the river switched back and forth between these established nodes.

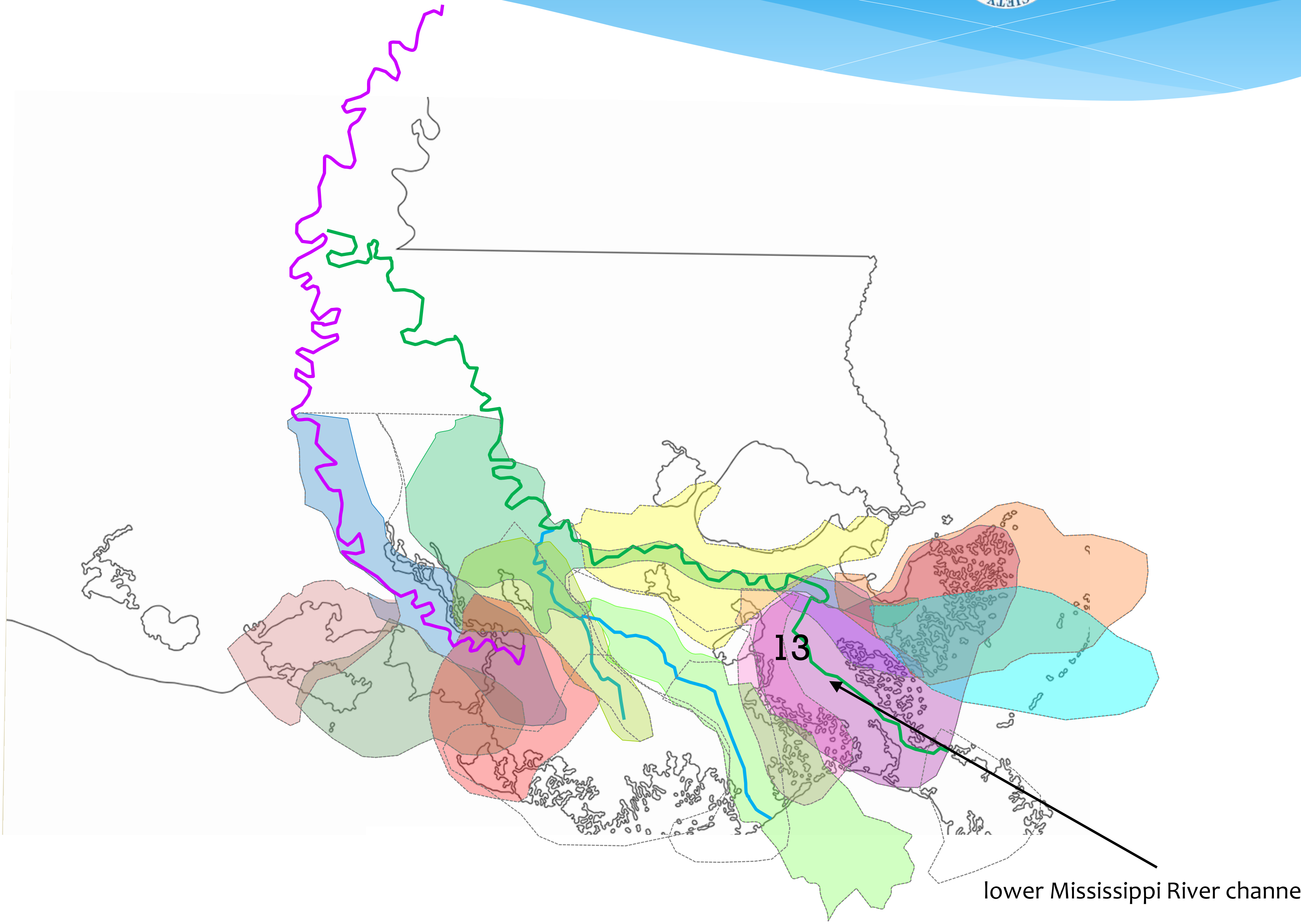


Bayou La Loutre
8
9
7
Bayou Des Familles

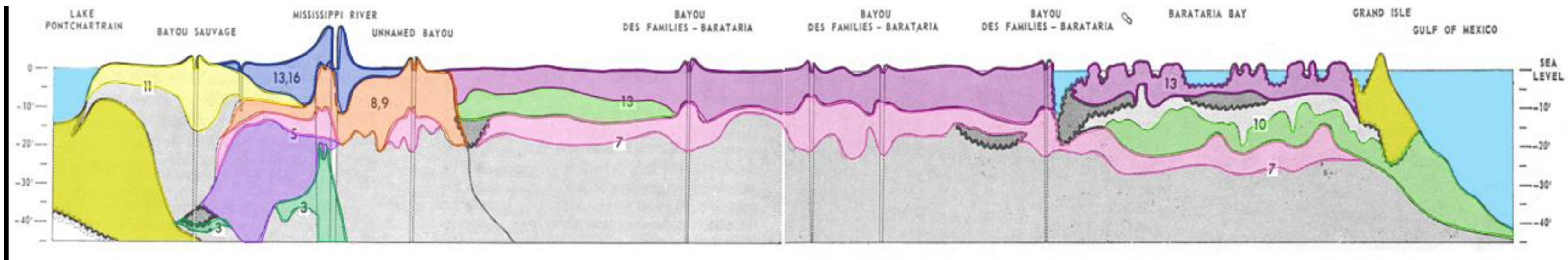

10
lower Bayou Lafourche

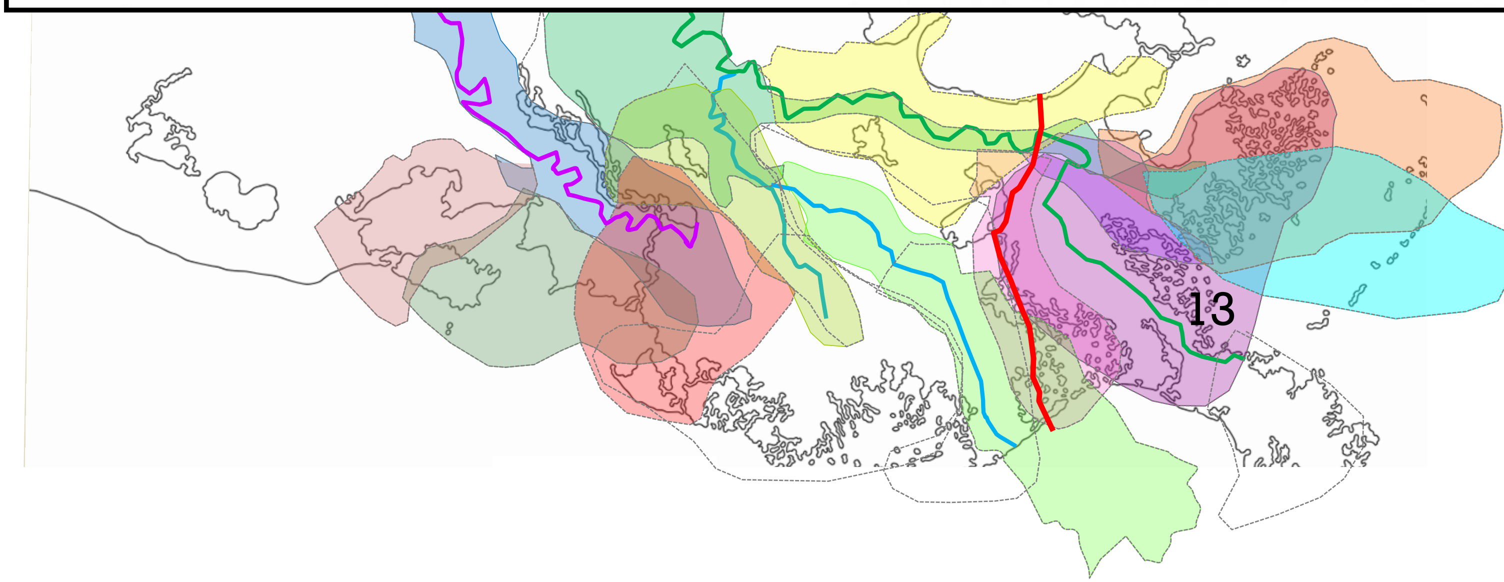

11
Bayou Sauvage

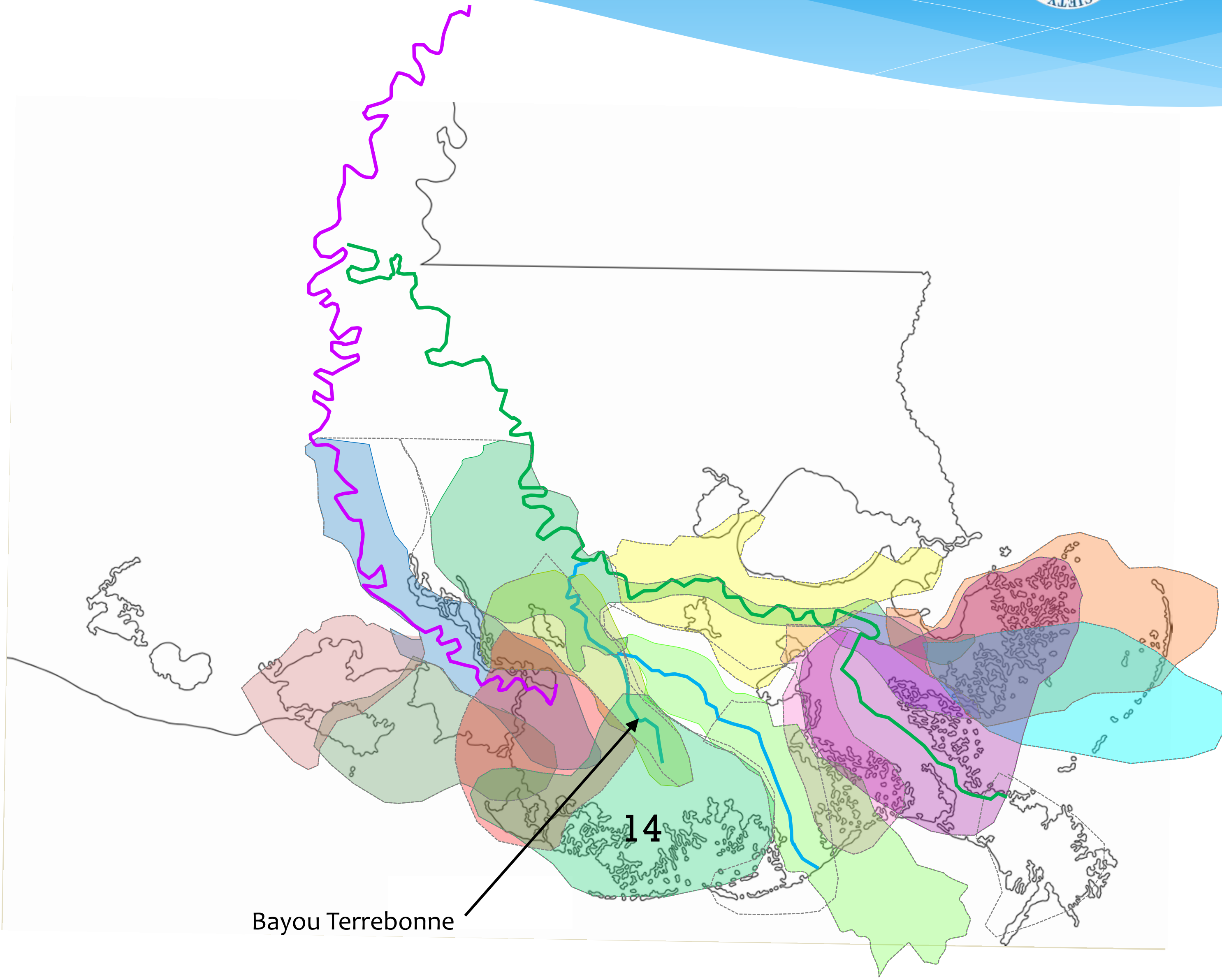

12

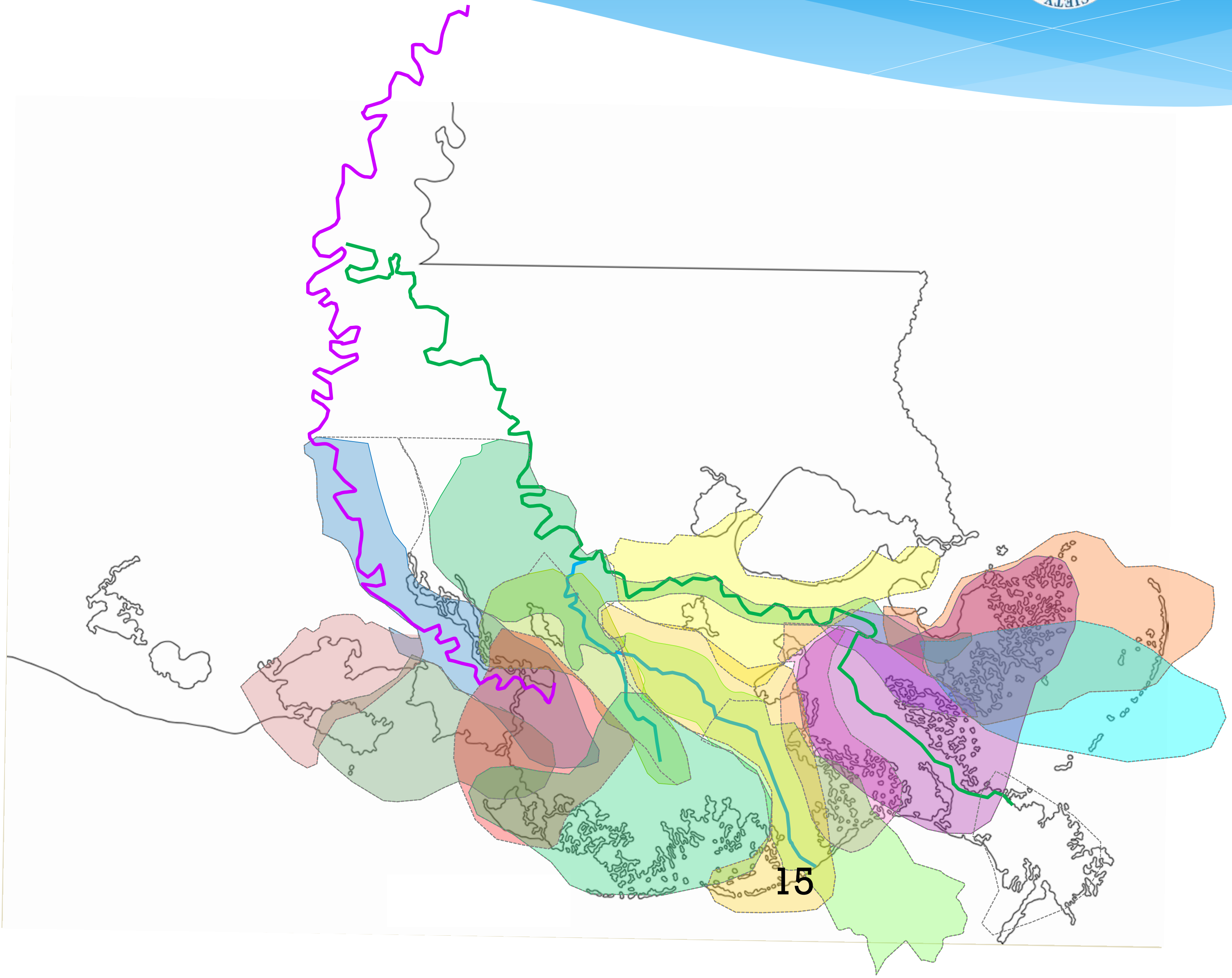

13
lower Mississippi River channel

One of Frazier's core profiles is shown as the red line extending from New Orleans to Grand Isle. It demonstrates one of the most significant aspects of building of the wetlands – that the delta deposits have been continuously subsiding throughout the building stage. At the southern end of the profile deltas number 7, 10 and 13 all appear to overlap on the map. The profile reveals this is because delta 7 subsided below the surface, then delta 10 built new land in the same area and subsided below the surface. Delta 13 again rebuilt new land in the area and is now subsiding below the surface.






14
Bayou Terrebonne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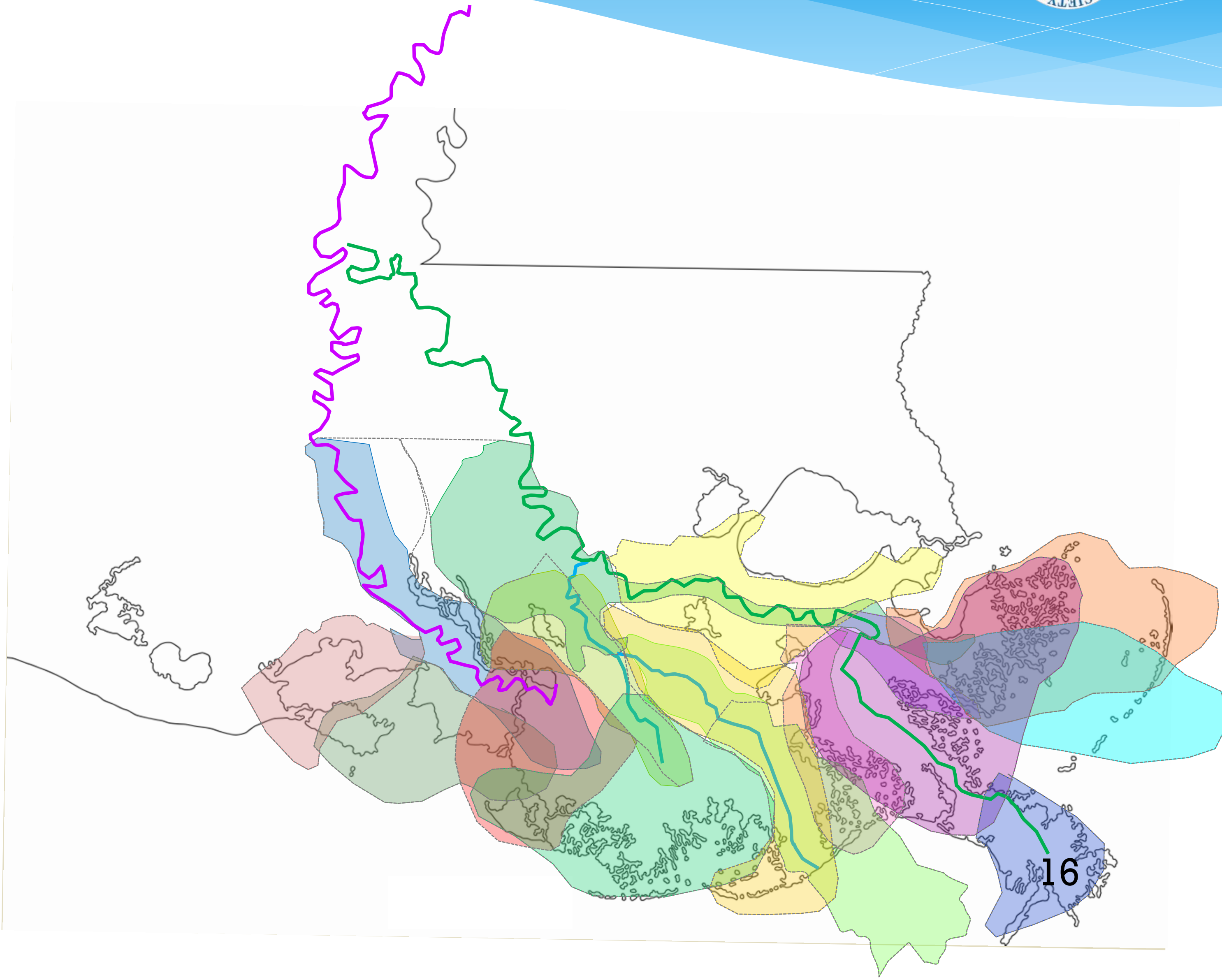
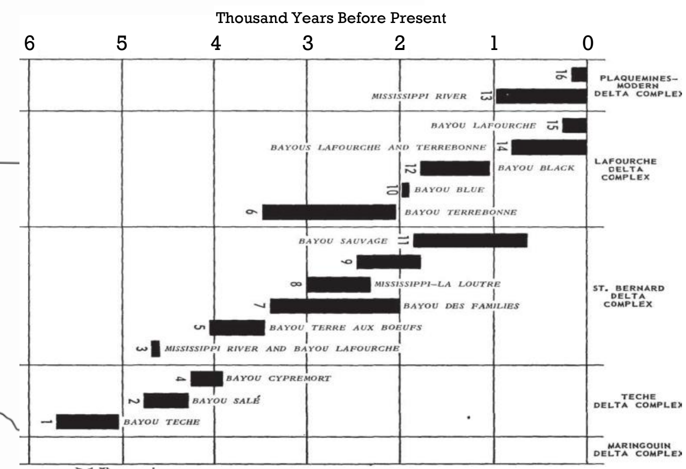
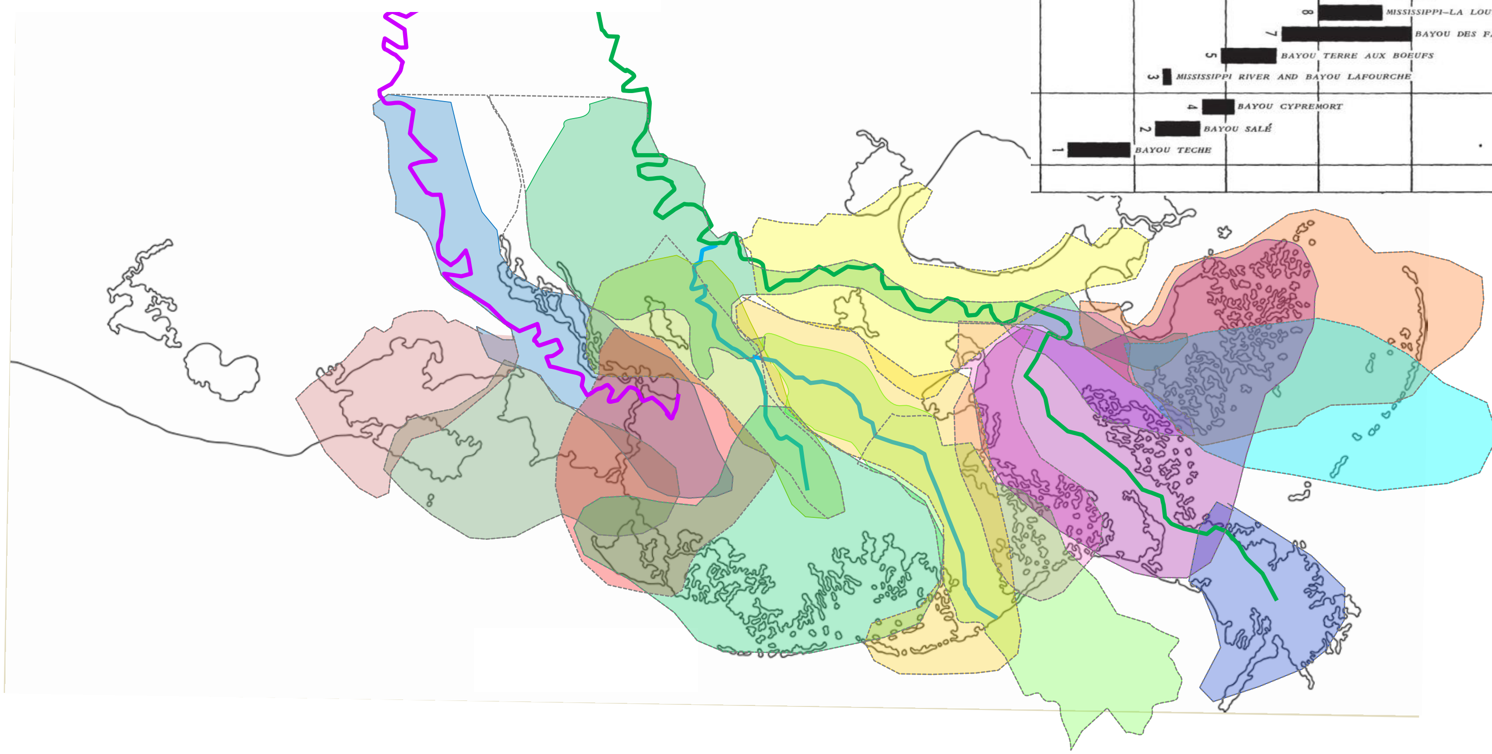
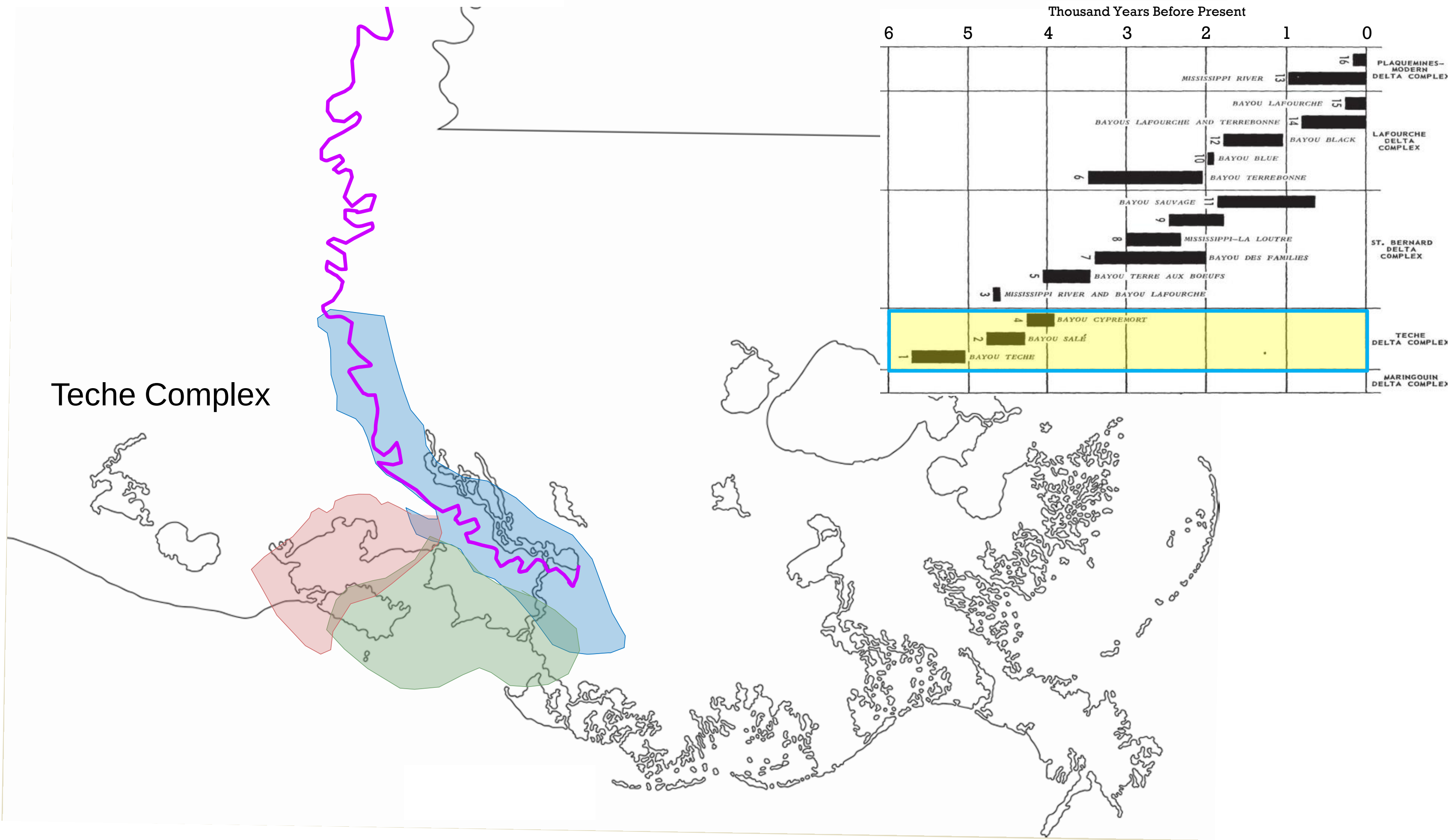

16

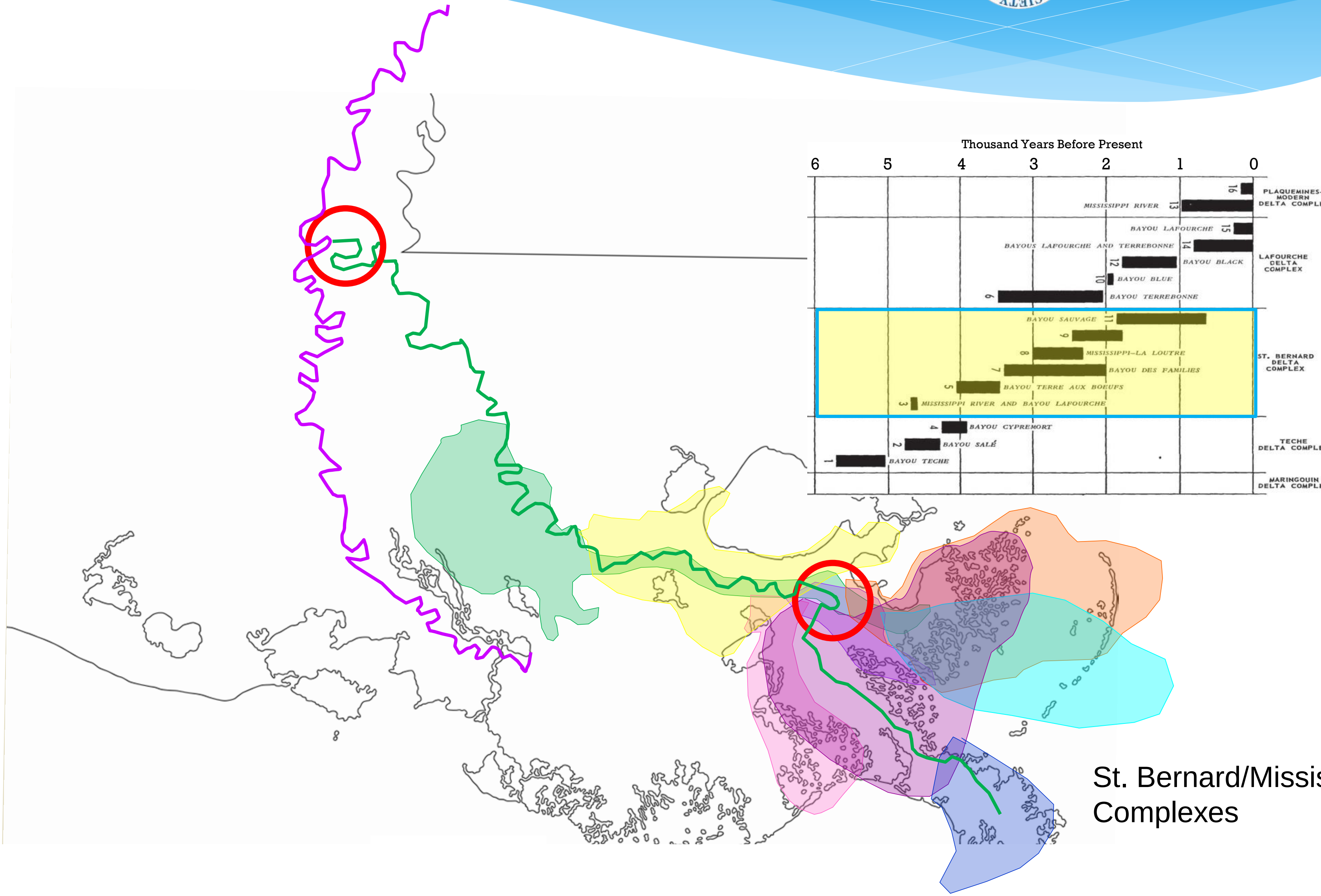
The majority of the surface area of the wetlands of south Louisiana is accounted for by the areas of the most recent historical deltas 11 through 16. Most of the rest of the historical deltas have subsided below the surface. It is critically important to understand that 6,000 year period of the building of the wetlands was a cyclical process in which land area was continuously being built and lost at the same time. The "no net loss" balance of land area was maintained in this way.



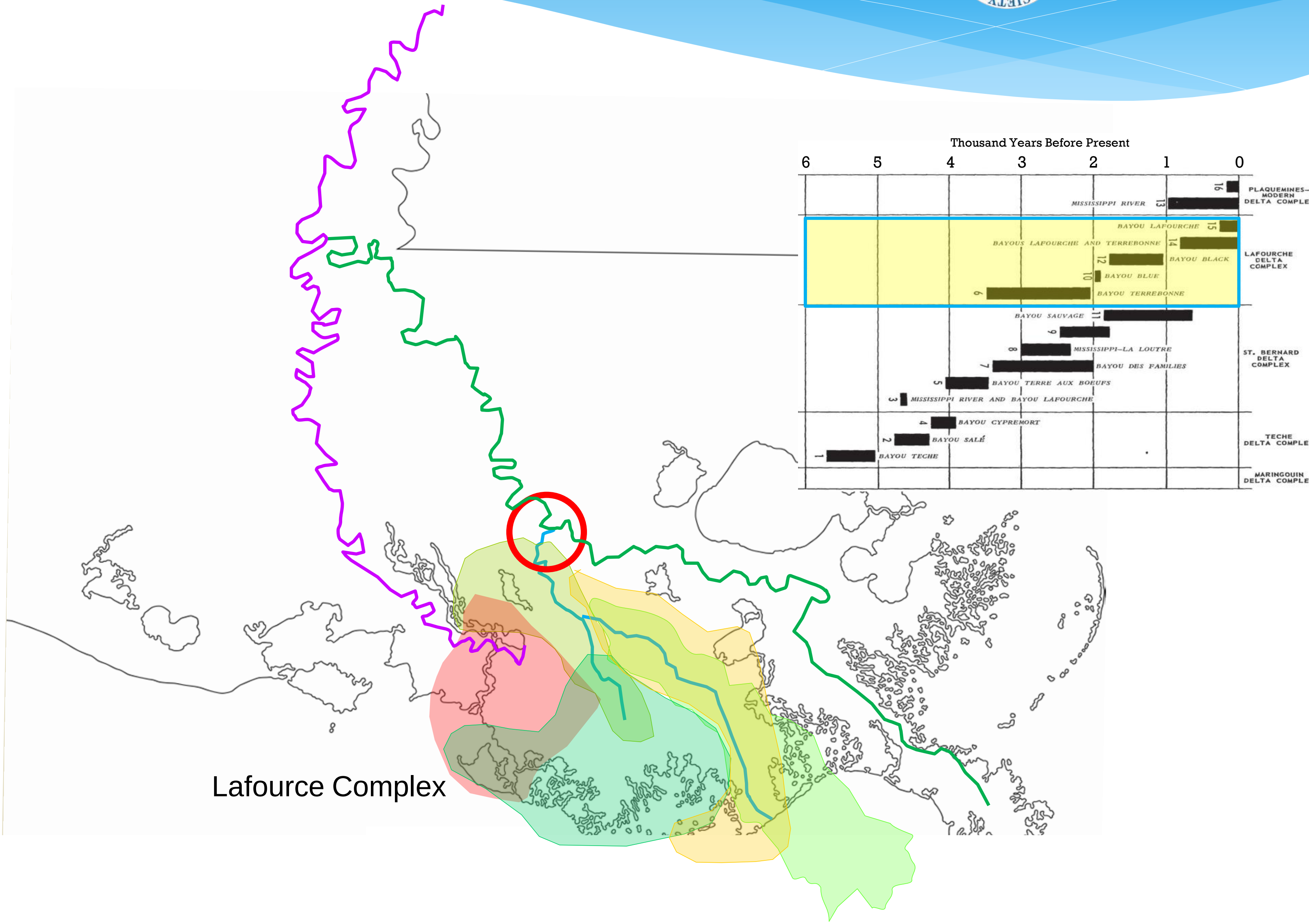


Frazier also grouped the deltas into “complexes”. After the formation of the original Teche Complex the succeeding ones share one of the major avulsion nodes.



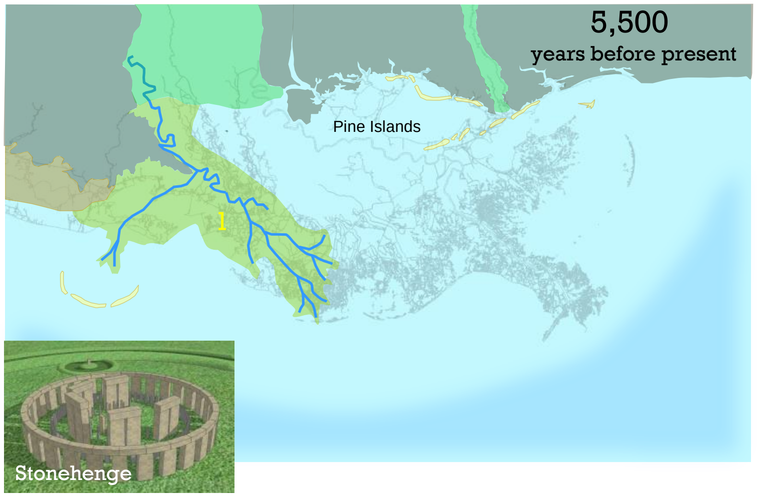


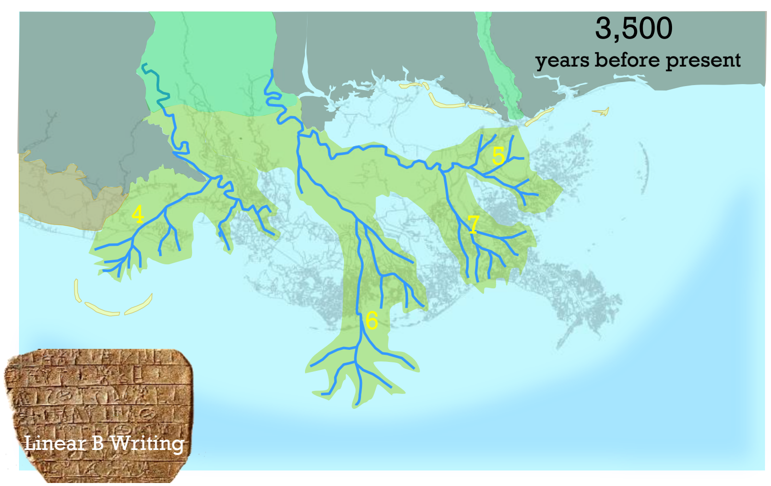
St. Bernard/Mississippi Complexes

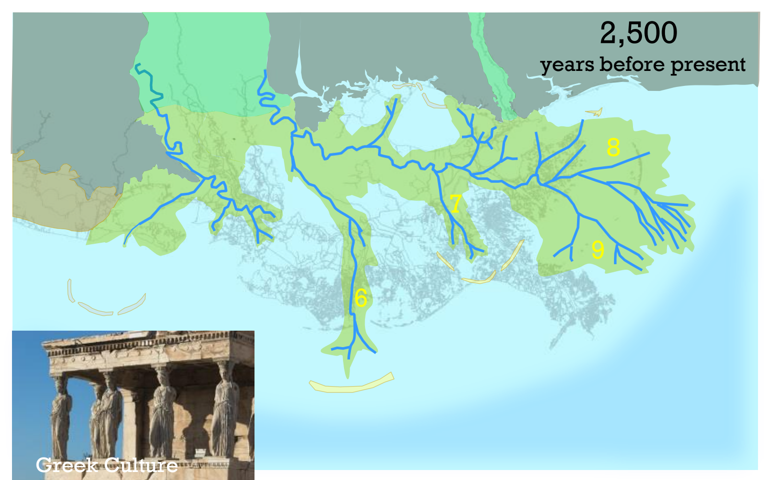


Thousand Years Before Present
6
5
4
3
2
1
0
16
13
MISSISSIPPI RIVER
PLAQUEMINES–MODERN DELTA COMPLEX
15
BAYOU LAFOURCHE
14
BAYOUS LAFOURCHE AND TERREBONNE
12
BAYOU BLACK
10
BAYOU BLUE
6
BAYOU TERREBONNE
LAFOURCHE DELTA COMPLEX
11
BAYOU SAUVAGE
9
8
MISSISSIPPI–LA LOUTRE
7
BAYOU DES FAMILIES
5
BAYOU TERRE AUX BOEUFS
3
MISSISSIPPI RIVER AND BAYOU LAFOURCHE
ST. BERNARD DELTA COMPLEX
4
BAYOU CYPREMORT
2
BAYOU SALÉ
1
BAYOU TECHE
TECHE DELTA COMPLEX
MARINGOUIN DELTA COMPLEX
Lafource Complex

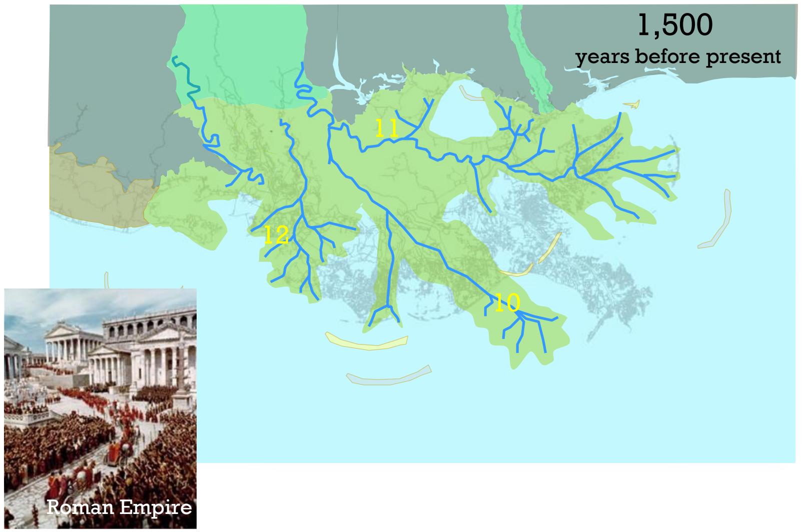
The Delta Cycle

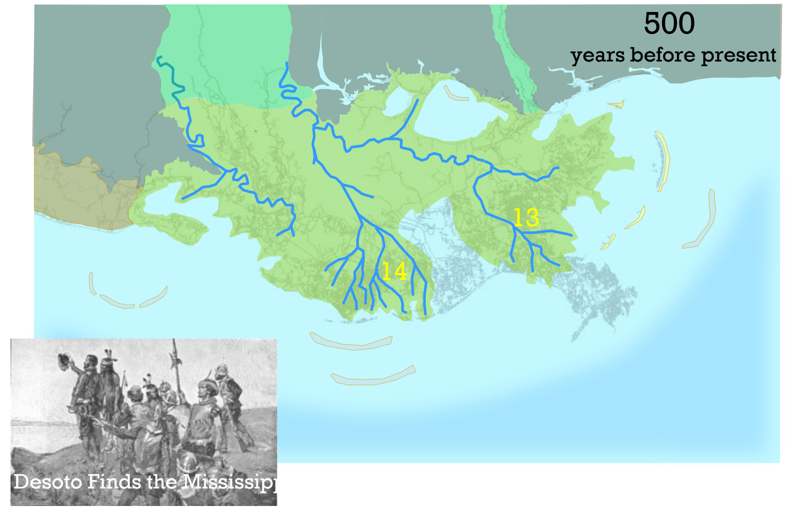


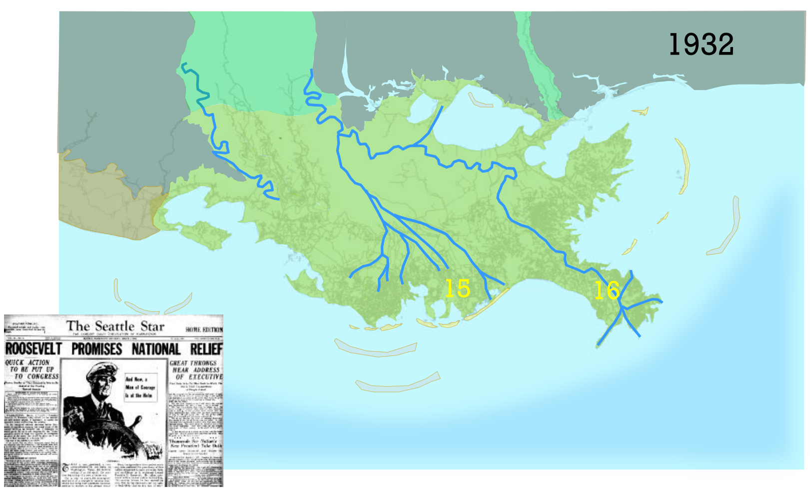




The Delta Cycle



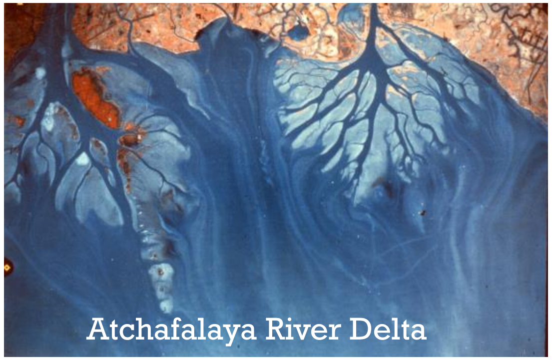


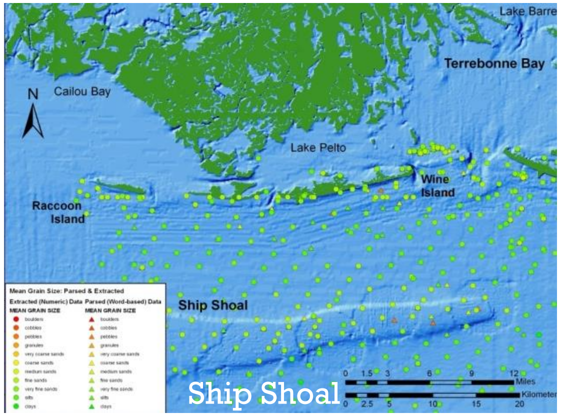


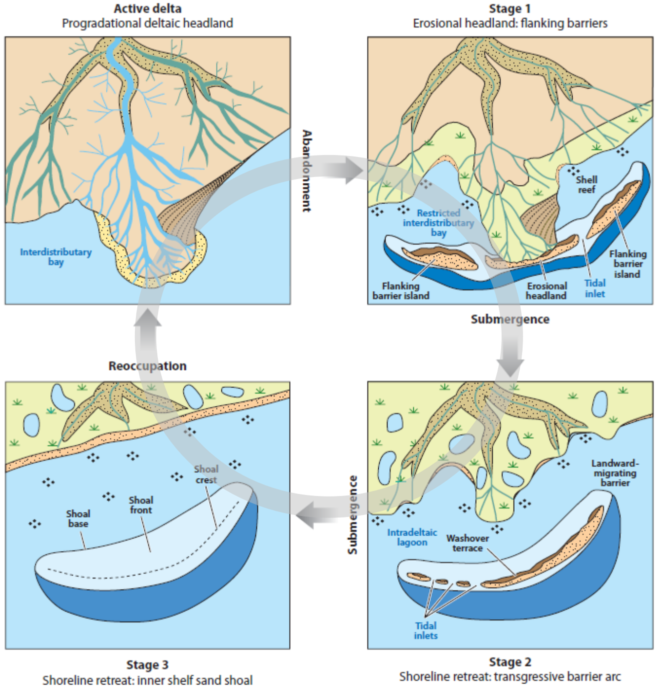
Frazier's temporal sequence of the Holocene deltas can be used to reconstruct "snap shot images" of what southeast Louisiana probably looked like at various points in time. The snap shot from 1932 serves as the baseline for all measurements of change in the wetlands because that was the first year that aerial photography was available to document measurable land area. Considering the previous configurations of the coast it is clear that change in land area – both gains and losses has been continuous throughout the late Holocene.

The Delta Cycle

natural evolution of the wetlands





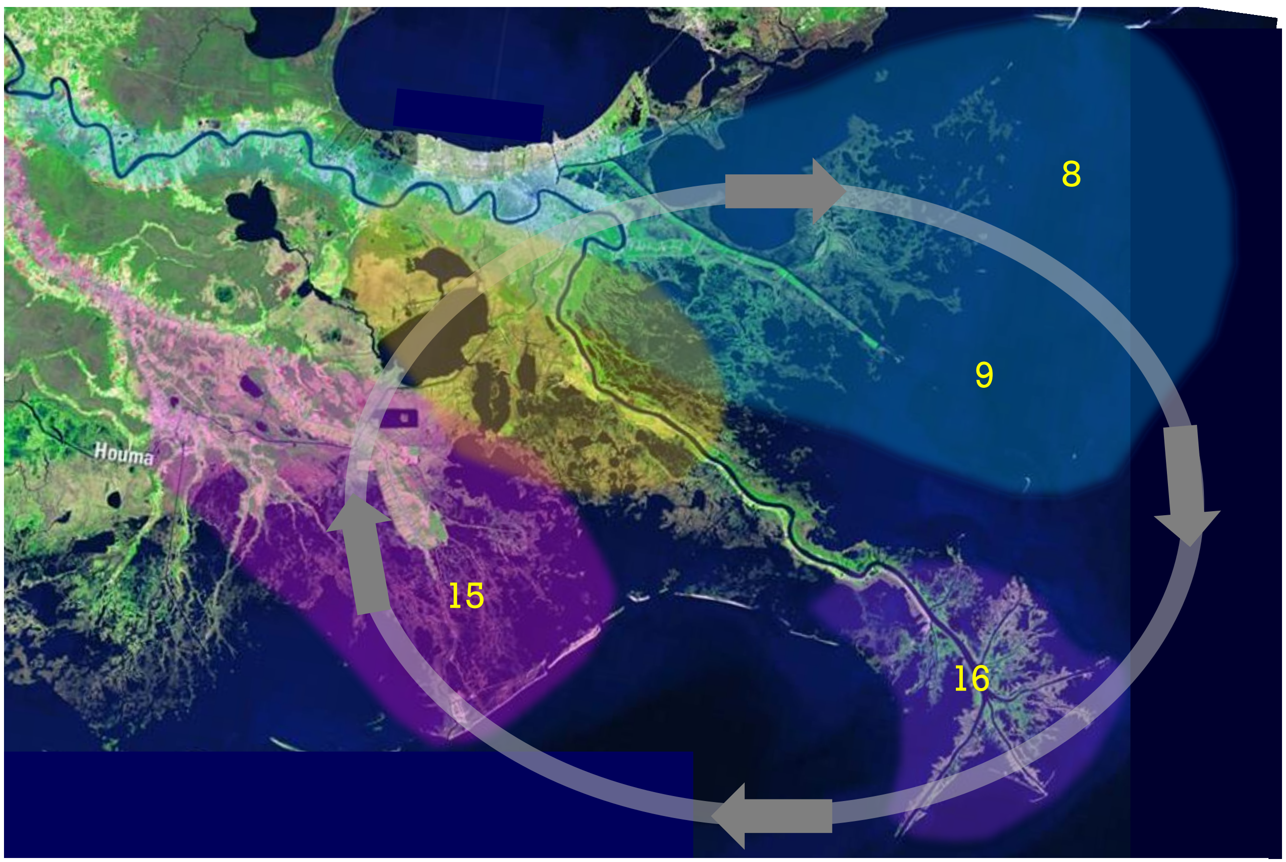


Several researchers have contributed to our understanding of the delta cycle. After the active delta is abandoned by an avulsion of the river it follows a succession of changes driven primarily by subsidence. Each stage in the cycle is represented by a land form at the surface today.

Roberts, H.H., 1997, Dynamic Changes of the Holocene Mississippi River Delta Plain: The Delta Cycle, Journal of Coastal Research., v. 13, p. 605-627

The Delta Cycle

natural evolution of the wetlands



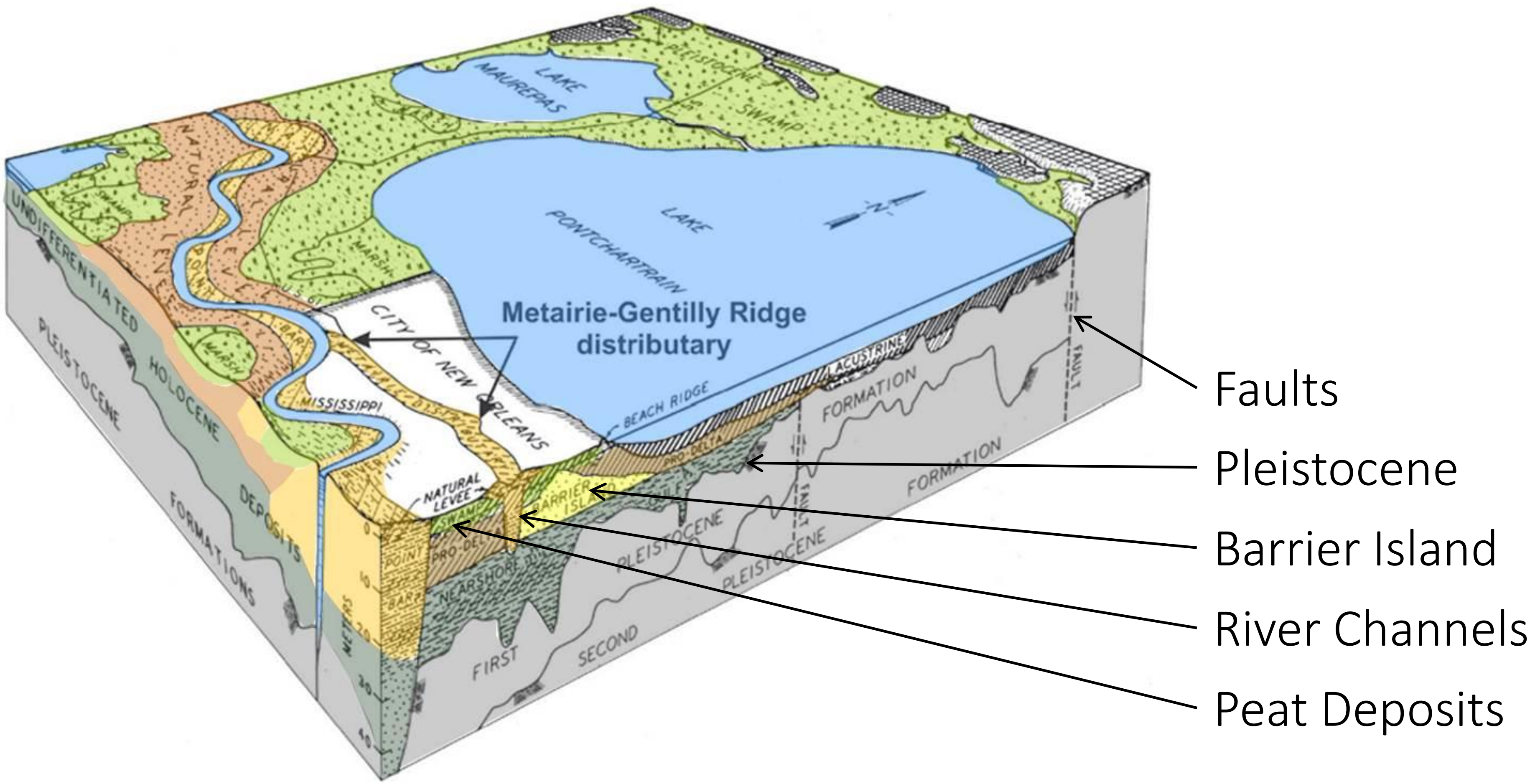
The delta cycle sequence can be seen in a comparison among deltas 8/9, 15 and 16.

The modern birdfoot delta (16) is rimmed by a set of sand bars at the distributary channel mouths. After abandonment these will be pushed inland to form a set of barrier islands and headland beaches as seen at Grand Isle and Fourchon on delta 15.

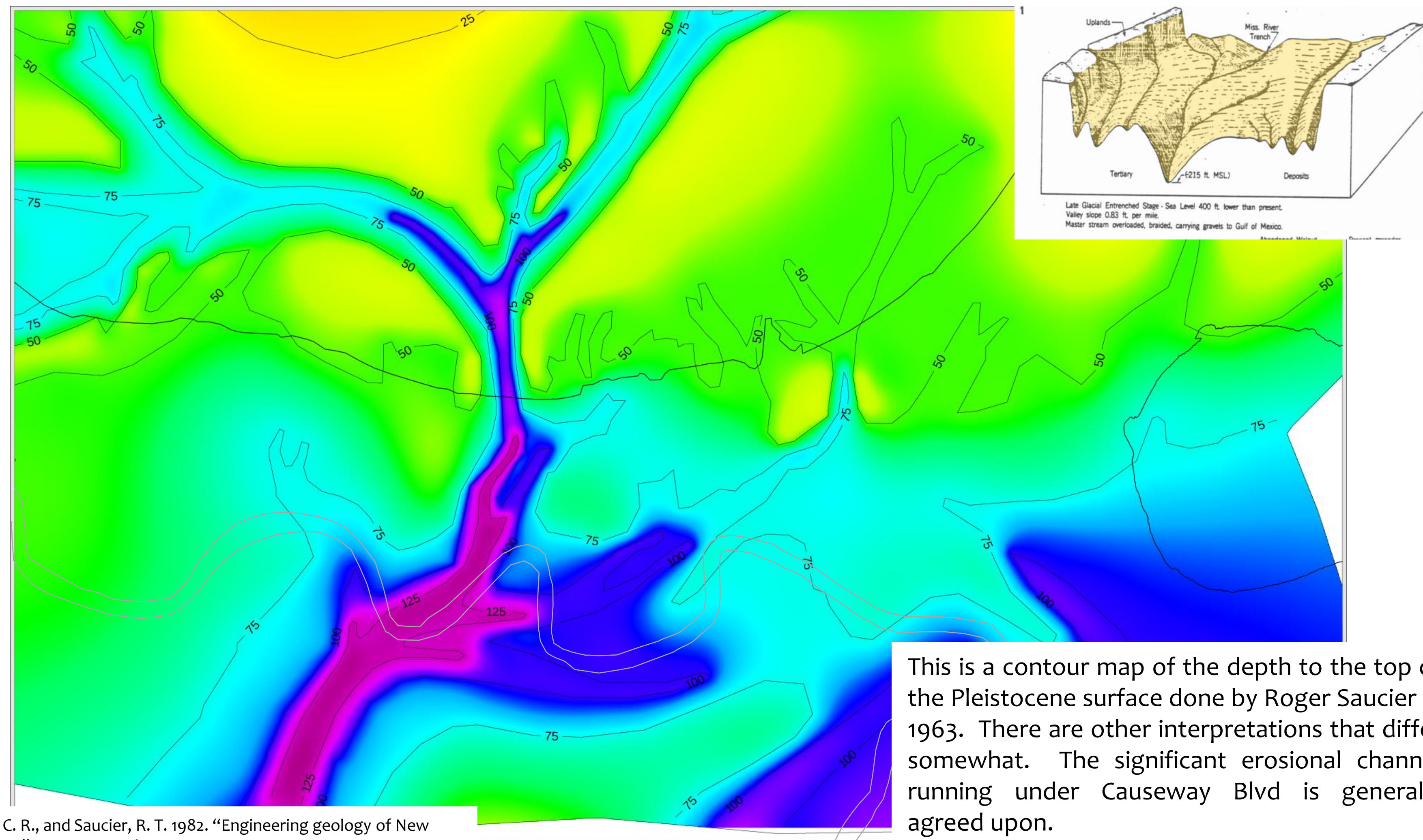
As time progresses the abandoned channel and adjacent marshes will also subside below the surface leaving the barrier islands and a shallow bay as is found at the Chandeleur Islands in delta 8/9

New Orleans
below the surface

The following sequence of slides with consider each of the essential elements of the shallow subsurface geology of New Orleans across the metro area.



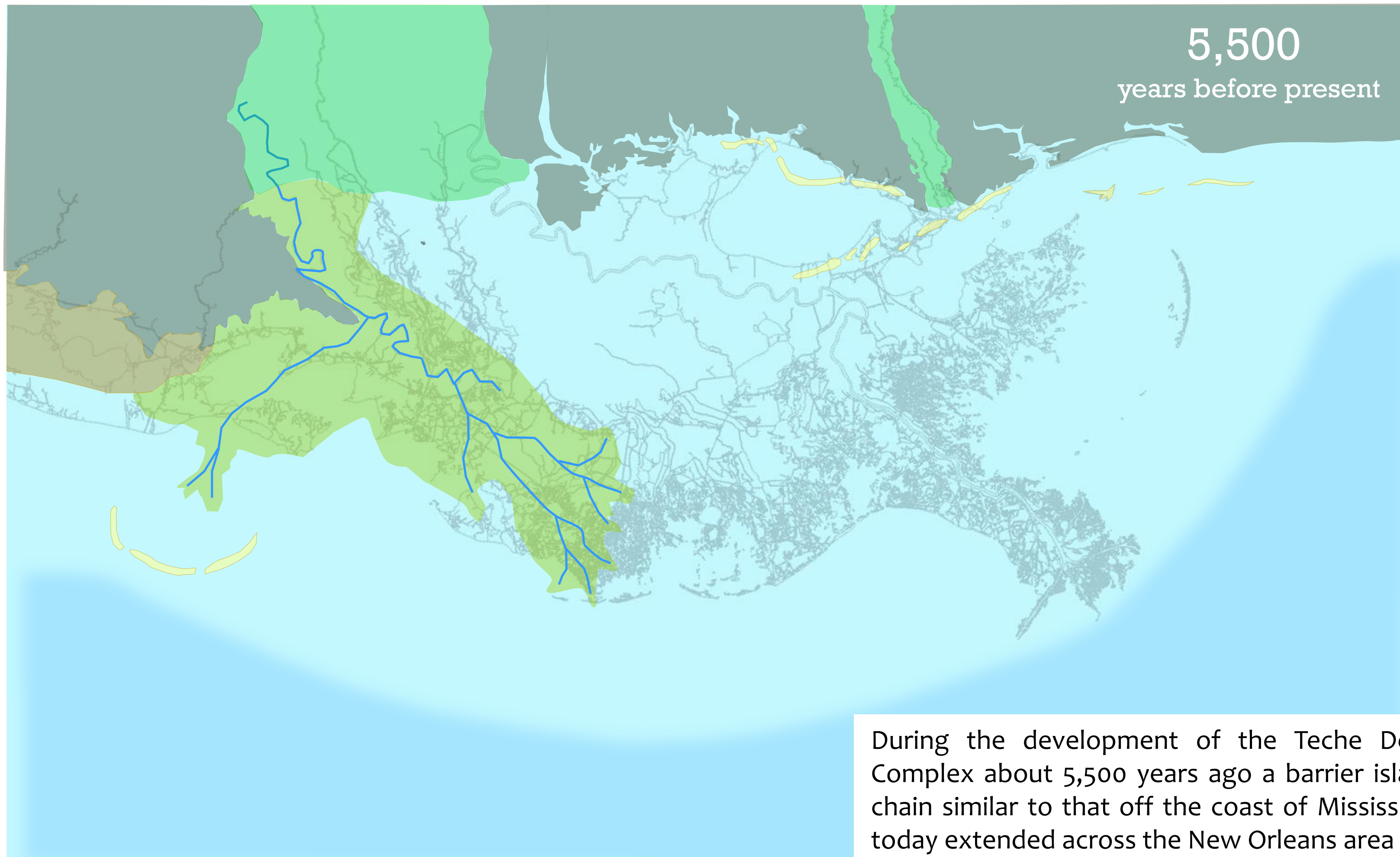
Pleistocene Surface



This is a contour map of the depth to the top of the Pleistocene surface done by Roger Saucier in 1963. There are other interpretations that differ somewhat. The significant erosional channel running under Causeway Blvd is generally agreed upon.

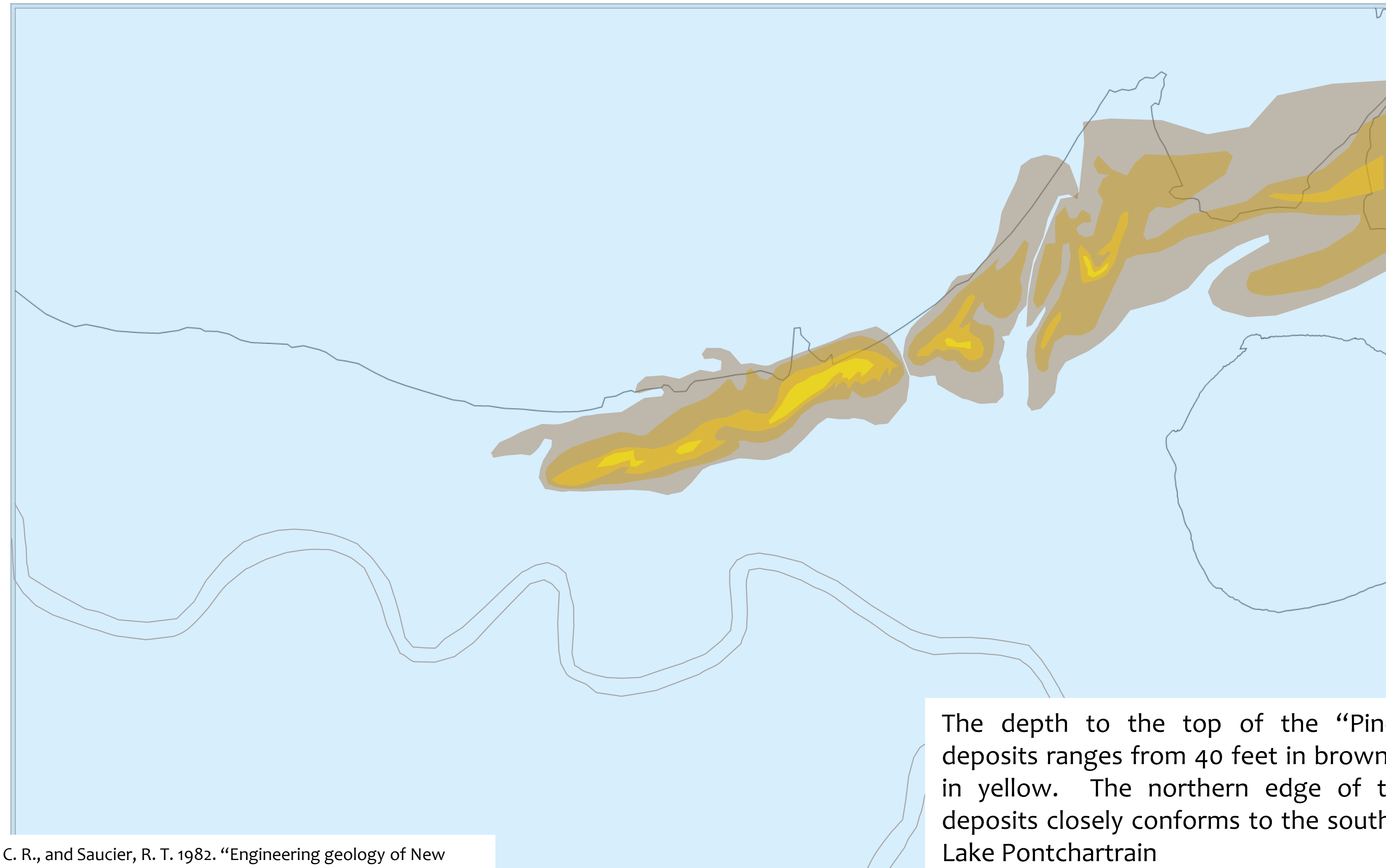
Kolb, C. R., and Saucier, R. T. 1982. "Engineering geology of New Orleans." Rev. Eng. Geol., 5, 75–93.

Building the Coastal Marshes



During the development of the Teche Delta Complex about 5,500 years ago a barrier island chain similar to that off the coast of Mississippi today extended across the New Orleans area

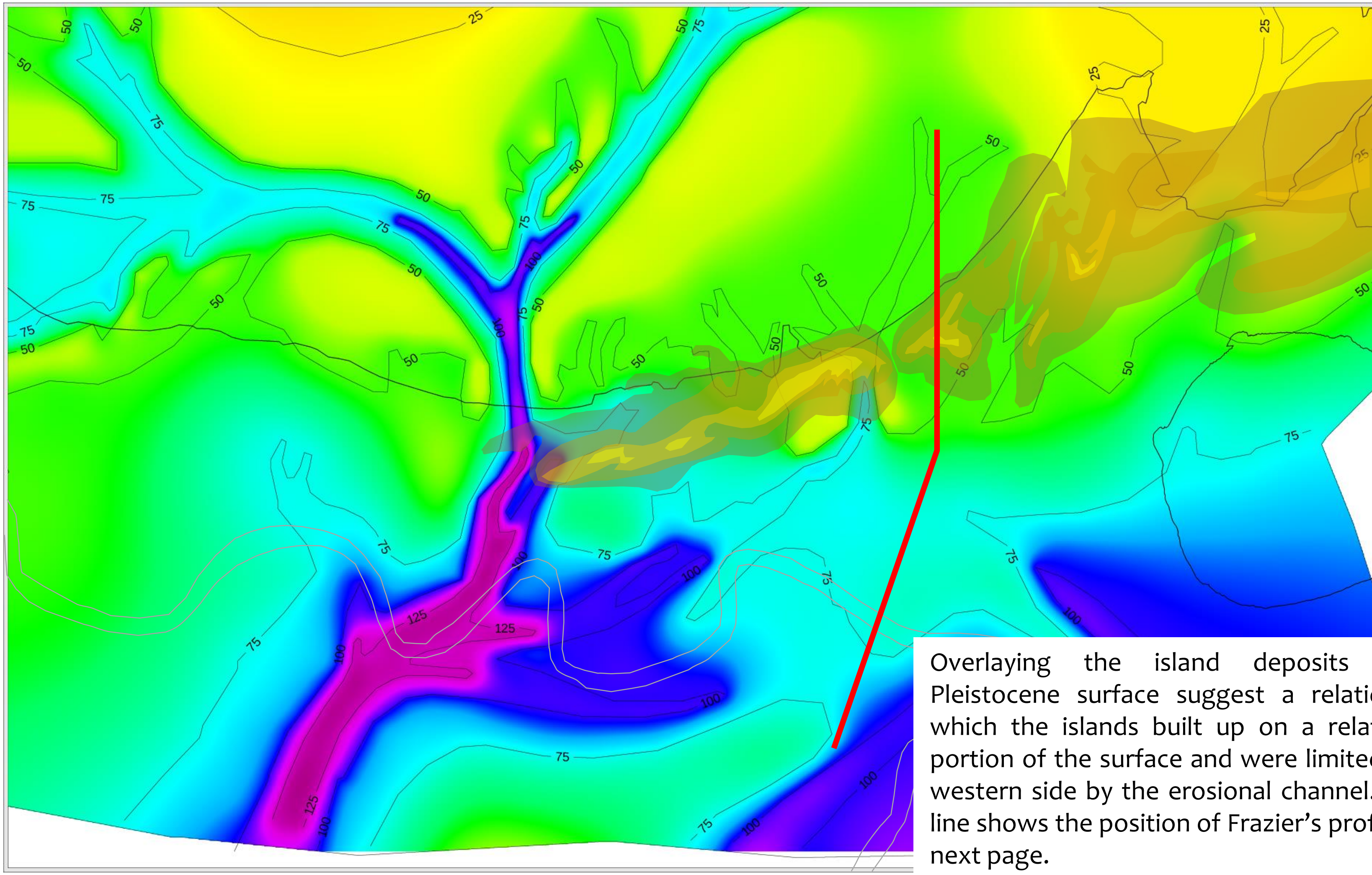
Pine Island Chain



The depth to the top of the "Pine Island" deposits ranges from 40 feet in brown to 5 feet in yellow. The northern edge of the island deposits closely conforms to the south shore of Lake Pontchartrain

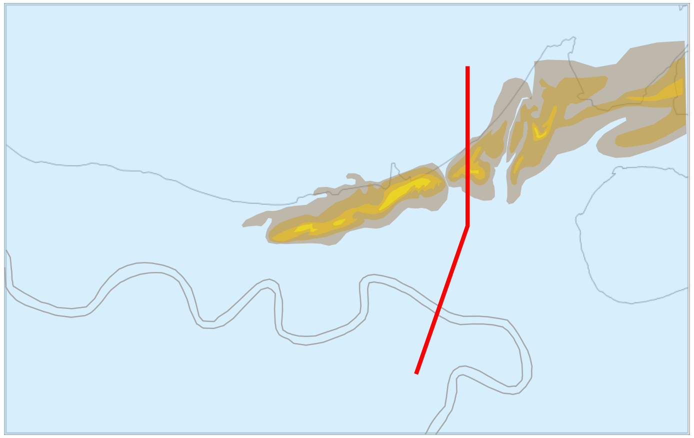
Kolb, C. R., and Saucier, R. T. 1982. "Engineering geology of New Orleans." Rev. Eng. Geol., 5, 75–93.

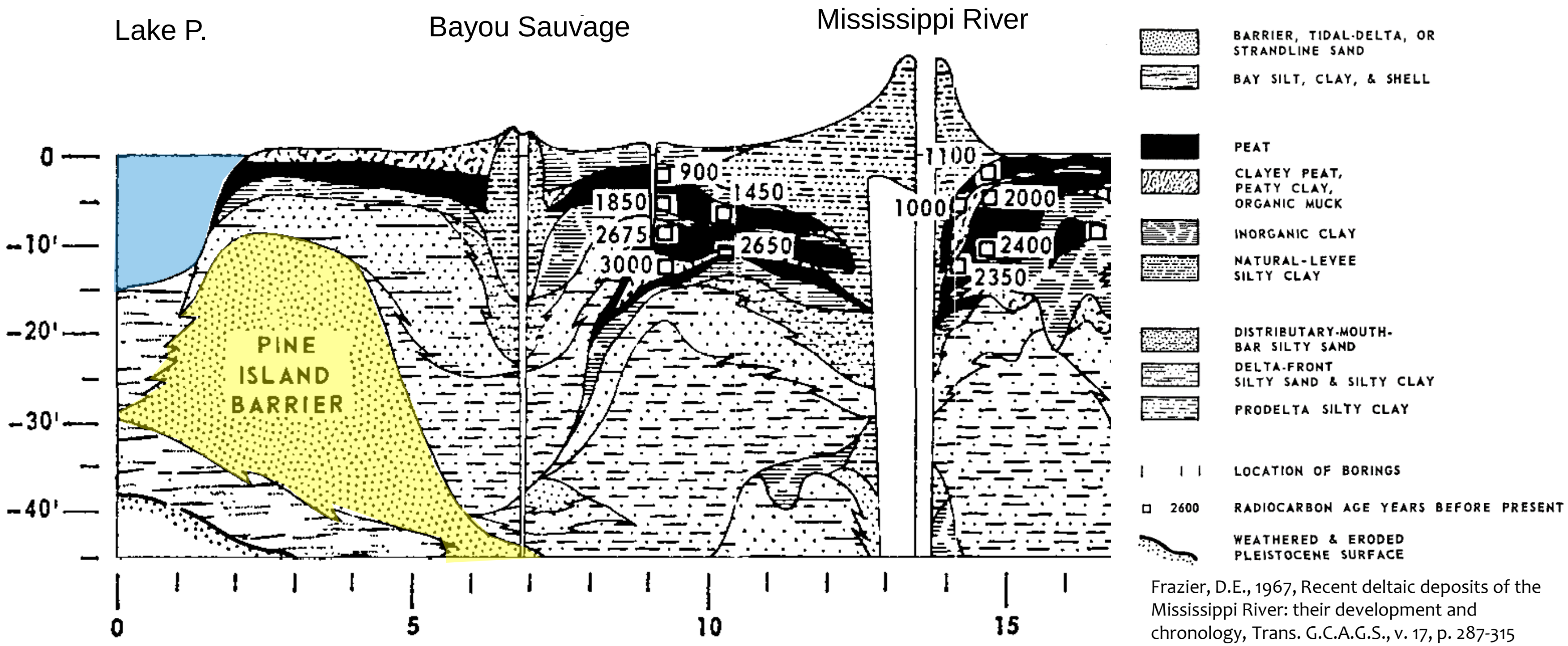
Pleistocene Surface



Overlaying the island deposits on the Pleistocene surface suggest a relationship in which the islands built up on a relatively flat portion of the surface and were limited on their western side by the erosional channel. The red line shows the position of Frazier's profile on the next page.

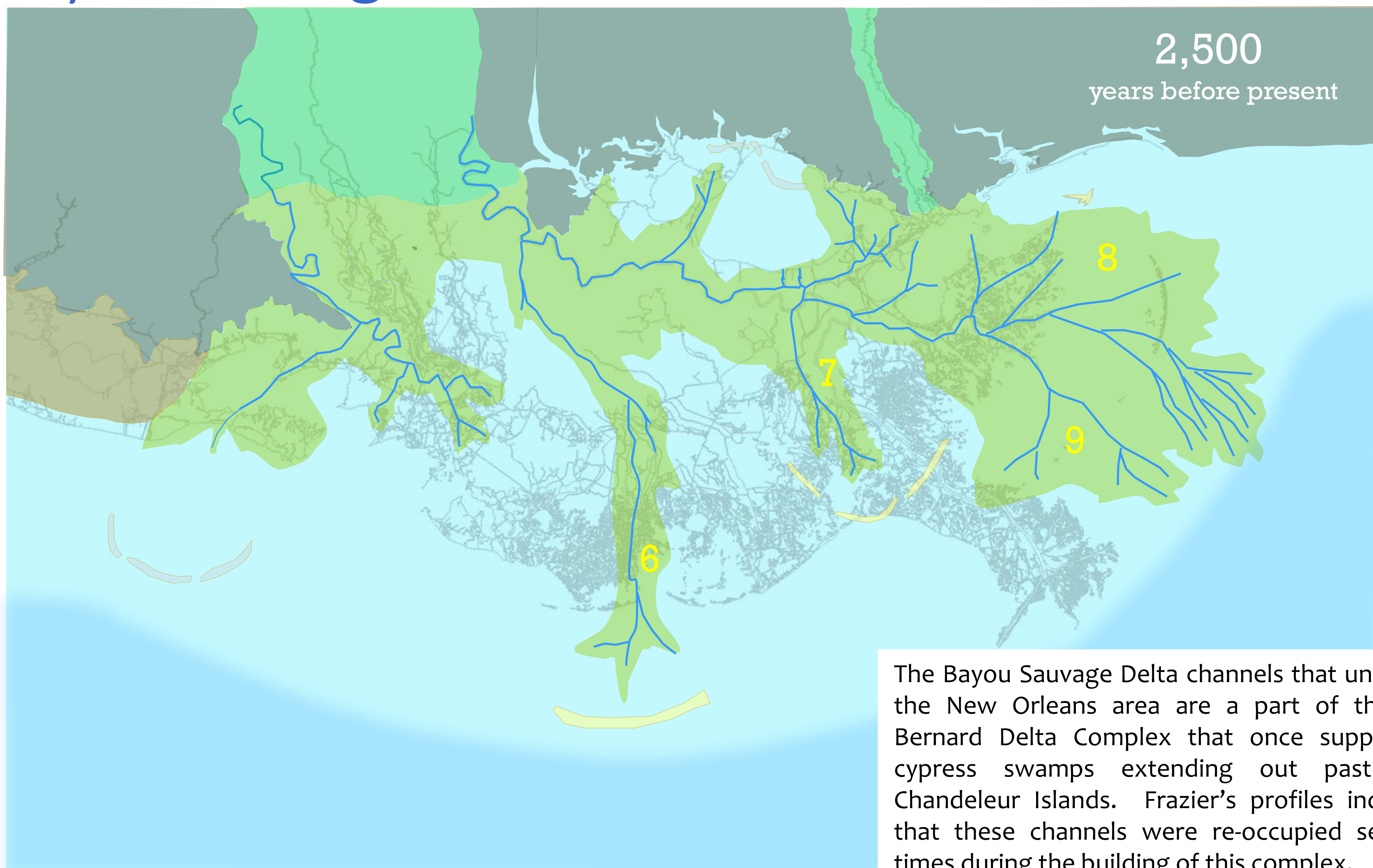
Sediment Core Profile





Frazier, D.E., 1967, Recent deltaic deposits of the Mississippi River: their development and chronology, Trans. G.C.A.G.S., v. 17, p. 287-315

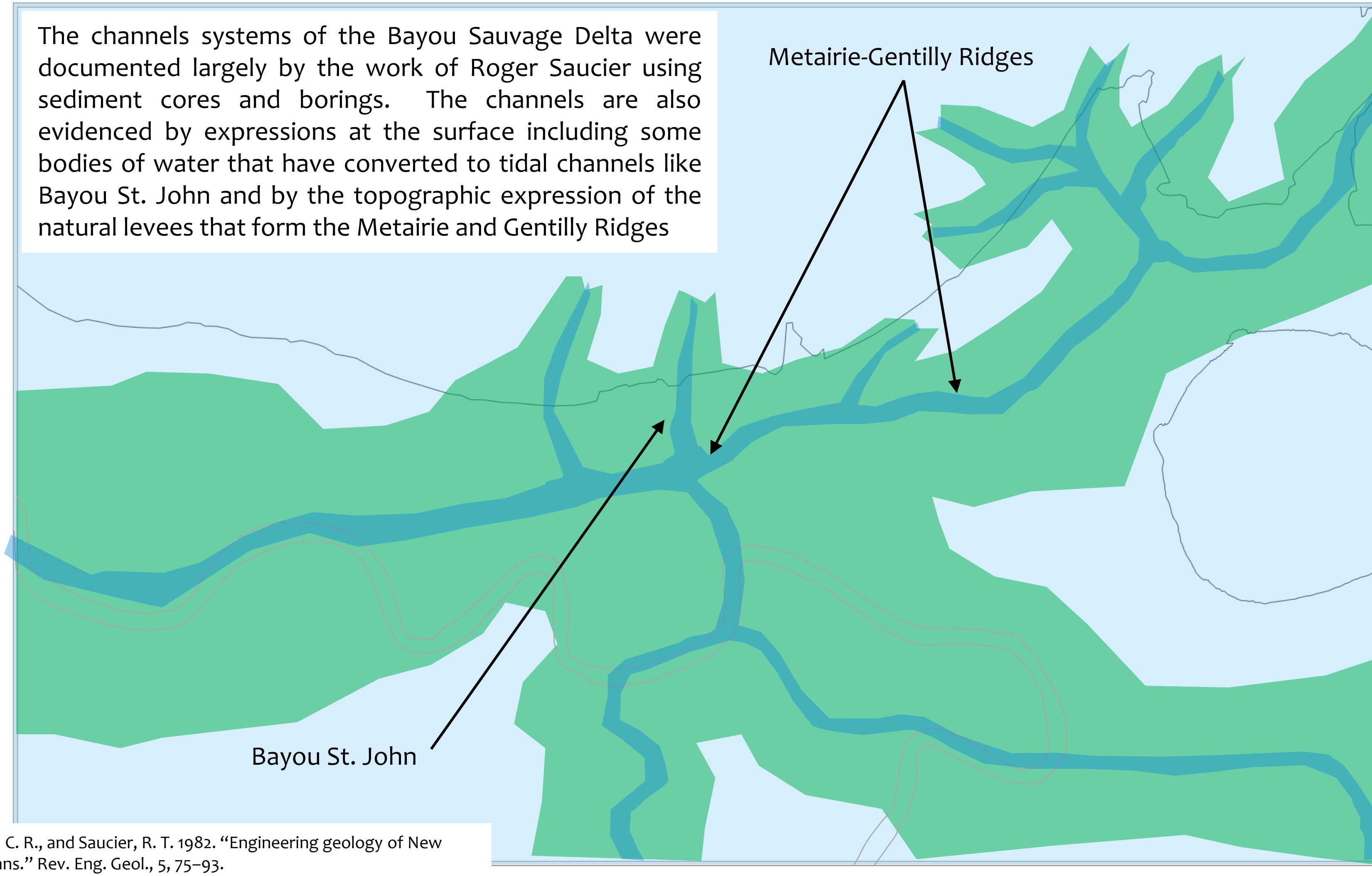
Bayou Sauvage Delta



The Bayou Sauvage Delta channels that underlie the New Orleans area are a part of the St. Bernard Delta Complex that once supported cypress swamps extending out past the Chandeleur Islands. Frazier's profiles indicate that these channels were re-occupied several times during the building of this complex.

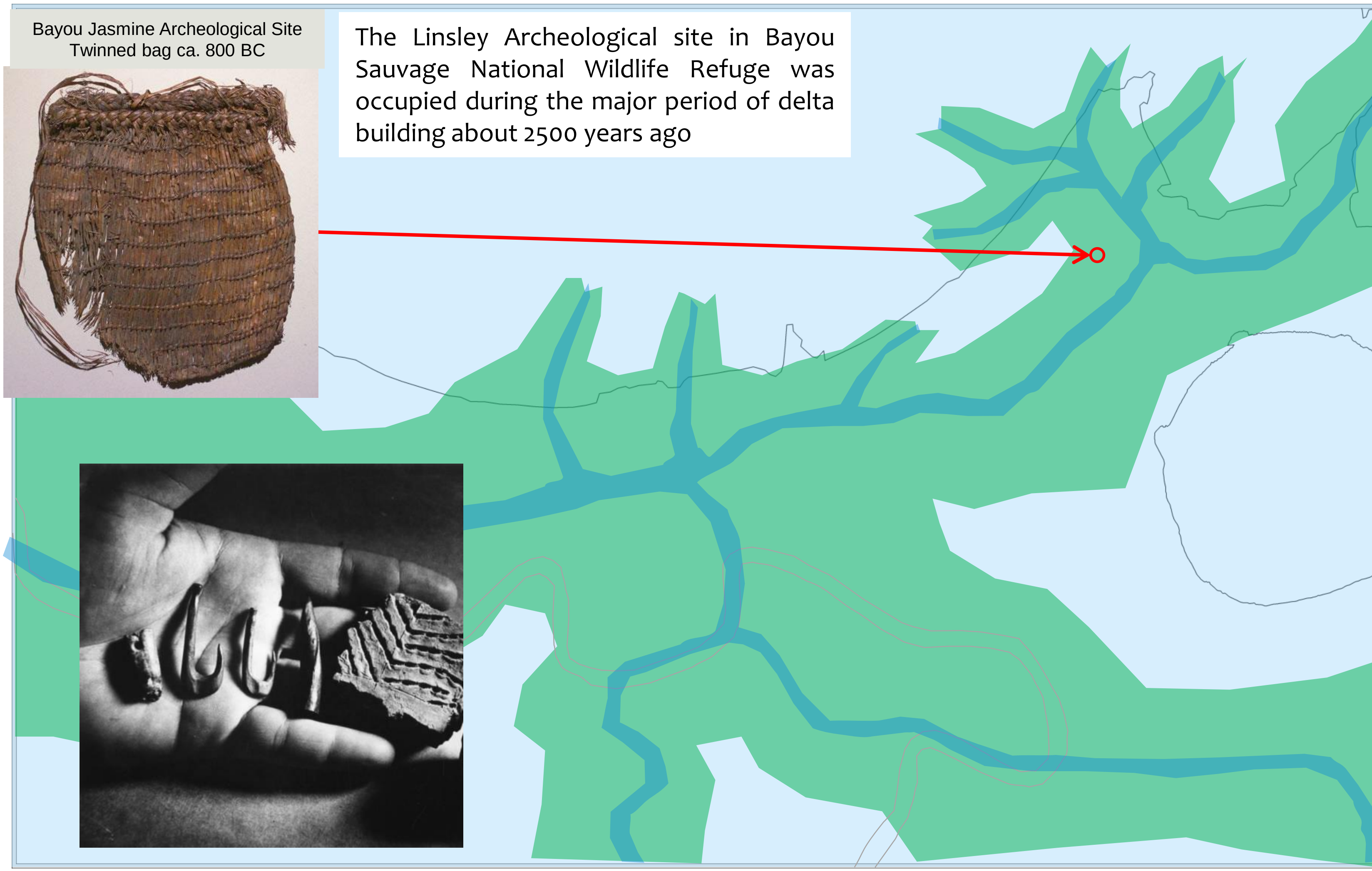
Bayou Sauvage Delta

The channels systems of the Bayou Sauvage Delta were documented largely by the work of Roger Saucier using sediment cores and borings. The channels are also evidenced by expressions at the surface including some bodies of water that have converted to tidal channels like Bayou St. John and by the topographic expression of the natural levees that form the Metairie and Gentilly Ridges



Kolb, C. R., and Saucier, R. T. 1982. "Engineering geology of New Orleans." Rev. Eng. Geol., 5, 75–93.

Bayou Sauvage Delta

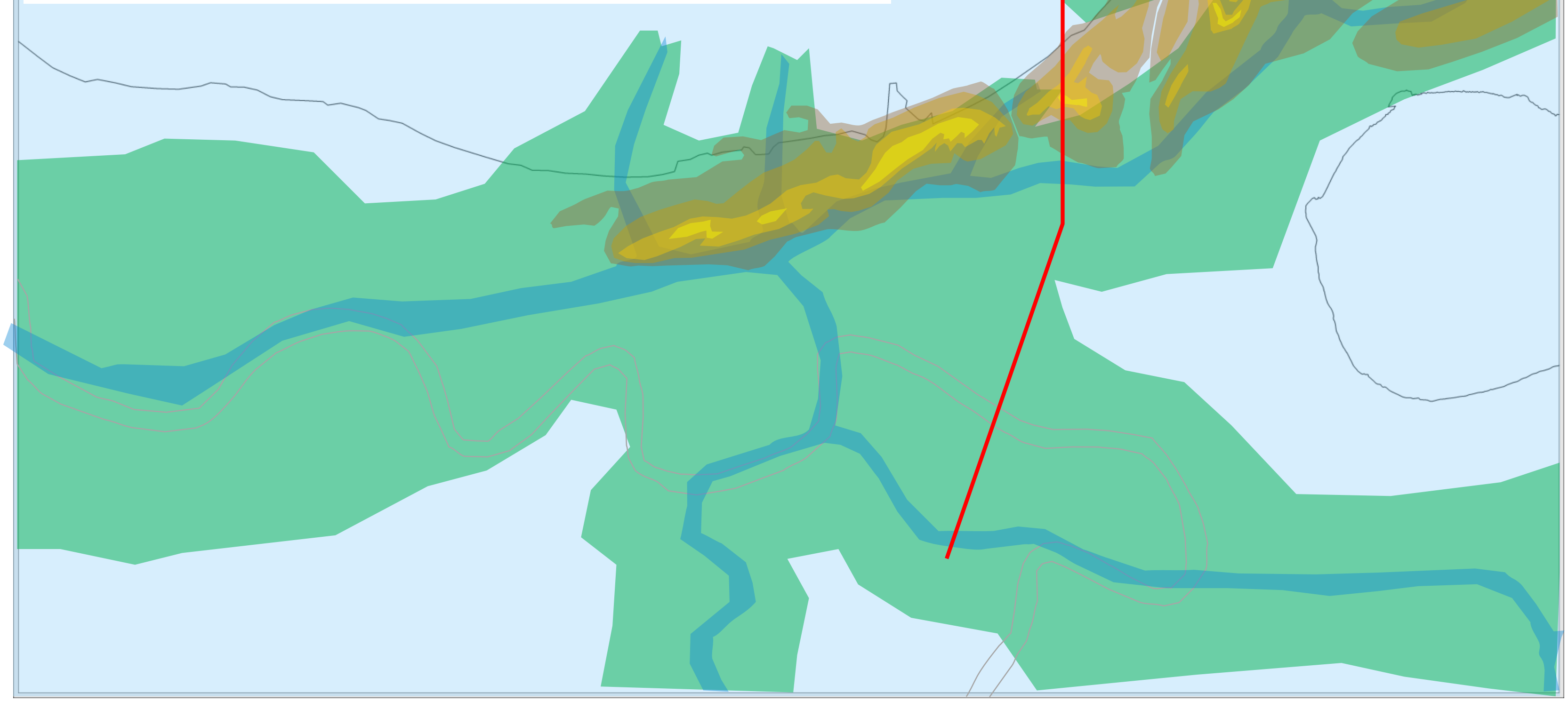


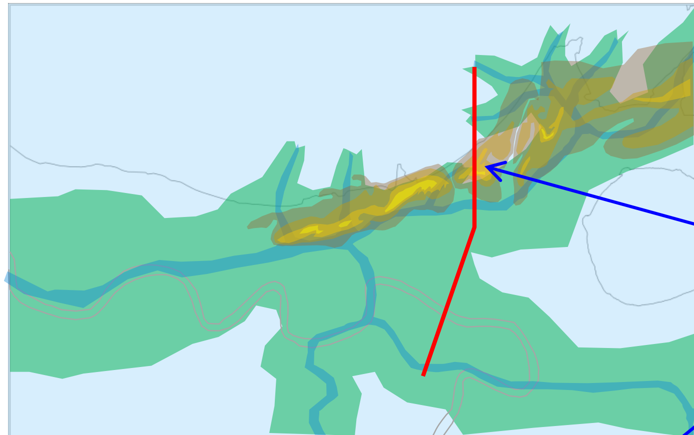
Bayou Jasmine Archeological Site
Twinned bag ca. 800 BC

The Linsley Archeological site in Bayou Sauvage National Wildlife Refuge was occupied during the major period of delta building about 2500 years ago

Bayou Sauvage Delta

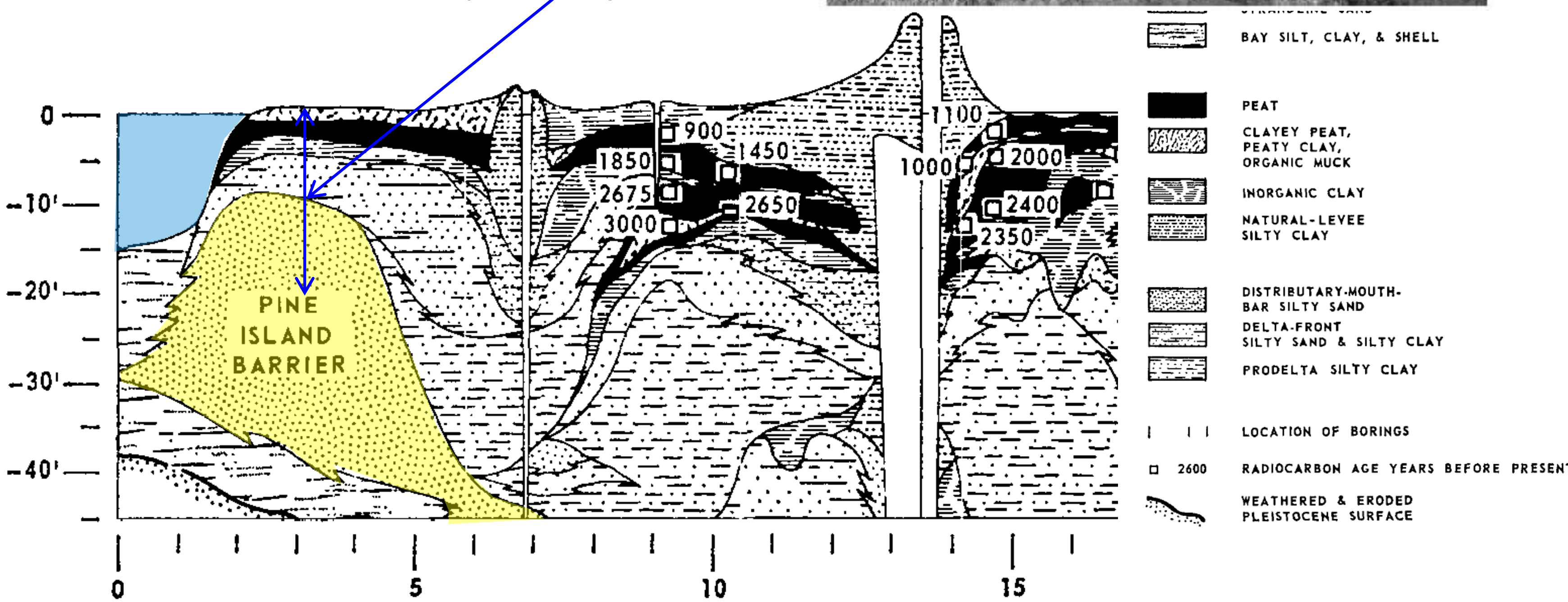
The east-northeastern course of the Bayou Sauvage Delta channels were clearly influenced by the deposits of the Pine Island barrier island chain that had probably submerged just below the surface at the time. The red line shows Frazier's profile on the next slide. The accompanying photograph from a pit on Bullard Road shows the dark delta deposits overlying the white sands of the barrier islands.





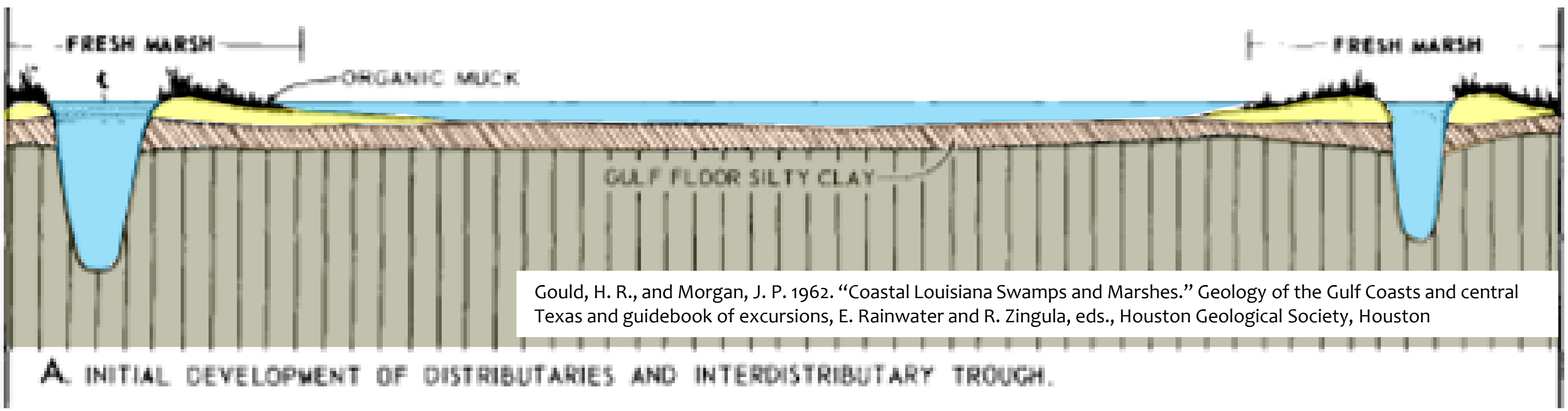
Lake P.

Bayou Sauvage



The Delta Cycle

natural evolution of the wetlands

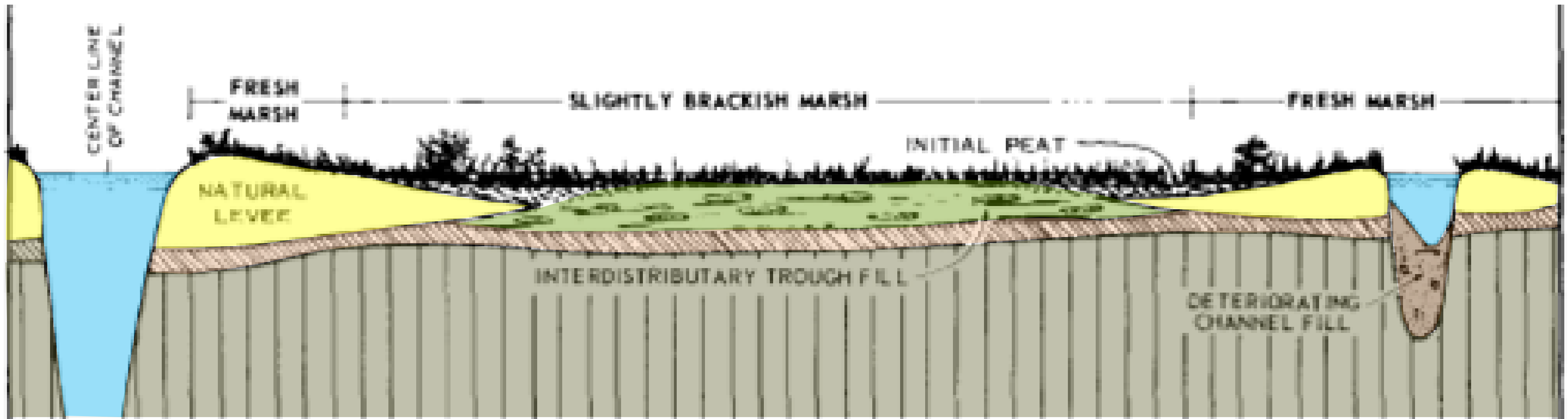


Gould, H. R., and Morgan, J. P. 1962. “Coastal Louisiana Swamps and Marshes.” Geology of the Gulf Coasts and central Texas and guidebook of excursions, E. Rainwater and R. Zingula, eds., Houston Geological Society, Houston

This sequence of slides illustrates some of the characteristics of the delta cycle in profile view. This is a generalized profile that is not directly representative of any one area, but it may be used to represent the succession of ecosystems that developed with the growth and abandonment of the Bayou Sauvage Delta system in the New Orleans area. This first stage coincides with the introduction of deltaic deposition on top of undifferentiated marine sediments of the early Holocene. The characteristic pattern of the natural levees of the channels is thickest near the channel and tapers away. These deposits are the foundation of the initial freshwater marsh.

The Delta Cycle

natural evolution of the wetlands

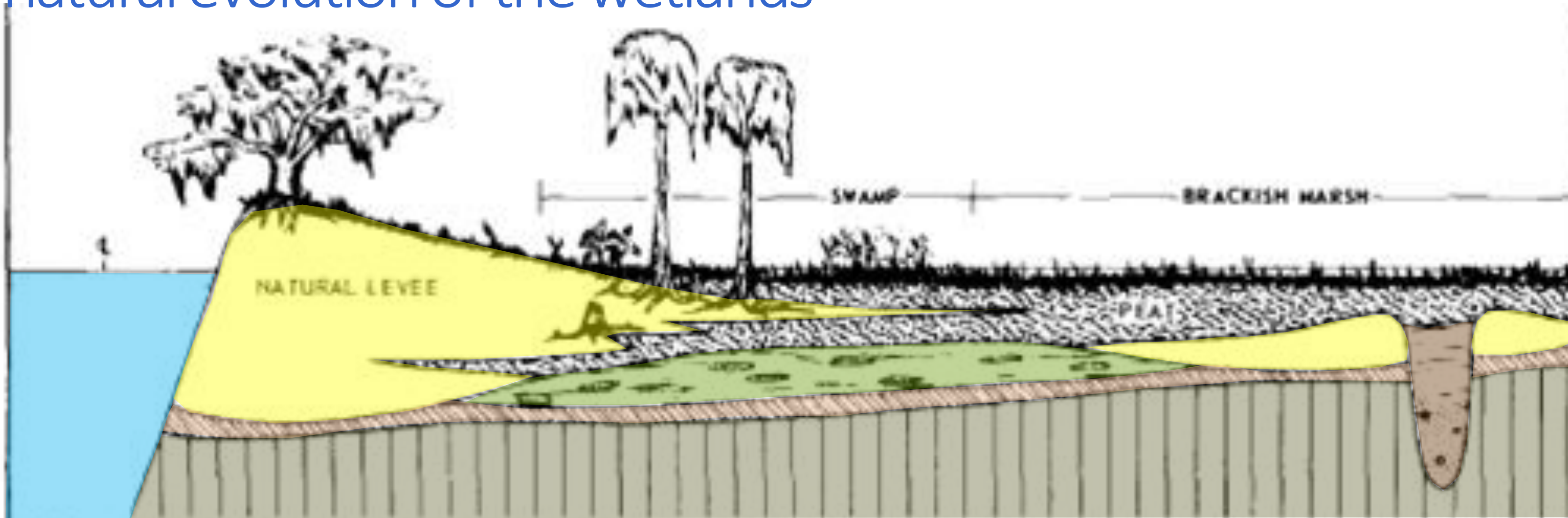


B. ENLARGMENT OF PRINCIPAL DISTRIBUTARY AND ITS NATURAL LEVEES – CREATION OF MARSHES IN TROUGH.

Subsidence and sediment accumulation progress as the delta develops. As long as there is sediment being delivered to the area, it can maintain and build elevation across the system. Between the distributary channels and away from the primary natural levee and crevasse splay deposition, the marshes can maintain elevation with sediment generally delivered by overbank flooding. This regular influx of freshwater keeps the marsh slightly brackish. Organic growth of the marsh at this stage forms the initial peat layers.

The Delta Cycle

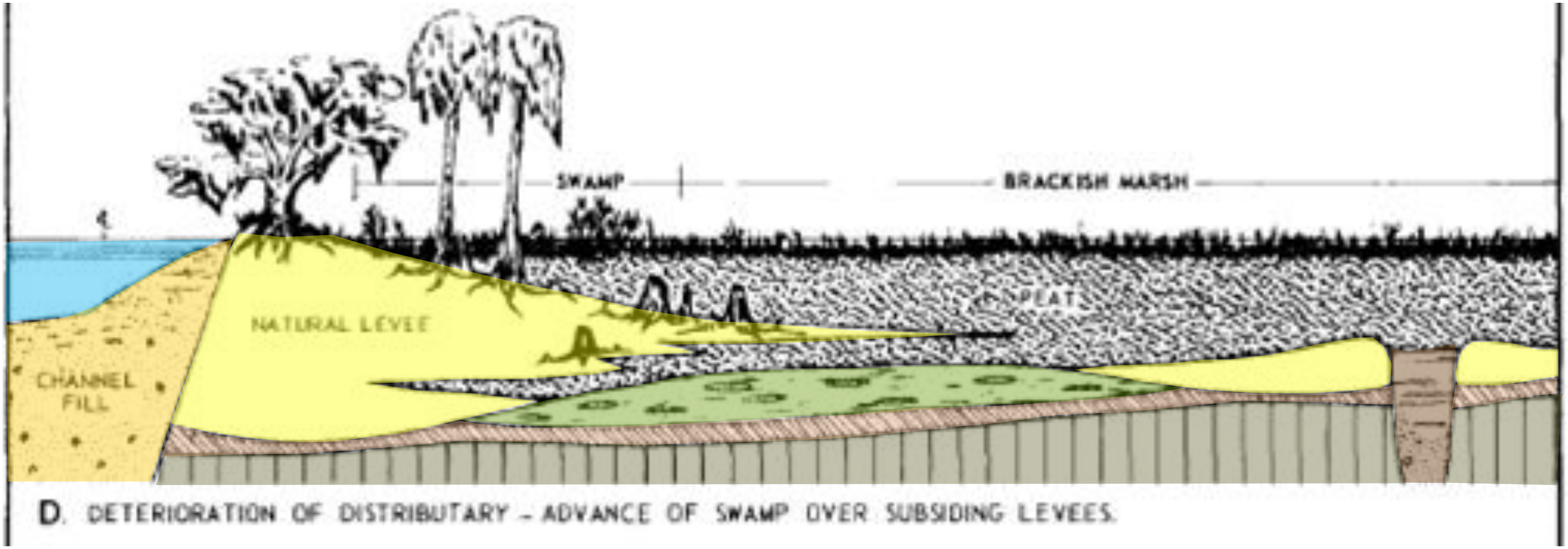
natural evolution of the wetlands



C. MAXIMUM DEVELOPMENT OF DISTRIBUTARY AND ITS NATURAL LEVEES – CREATION OF SWAMP AS LEVEE SUBSIDES.

In this conception the channel to the right has been abandoned and in the absence of an adequate sediment supply it subsides below the surface and is covered the by the organic growth of the brackish marsh away from the main channel to the left. The main channel is in its peak stage of development and it has built elevation capable of supporting cypress swamps along its flanks and oak trees along the crest of the natural levee. The peat layer continues to build thickness as the marsh plants grow at a rate necessary to maintain an elevation just above sea level. This type of vertical accretion of the land surface by organic growth still requires some mineral sediment input which is incorporated into the peat. Sediment is delivered by the annual flood cycle that tops the natural levees.

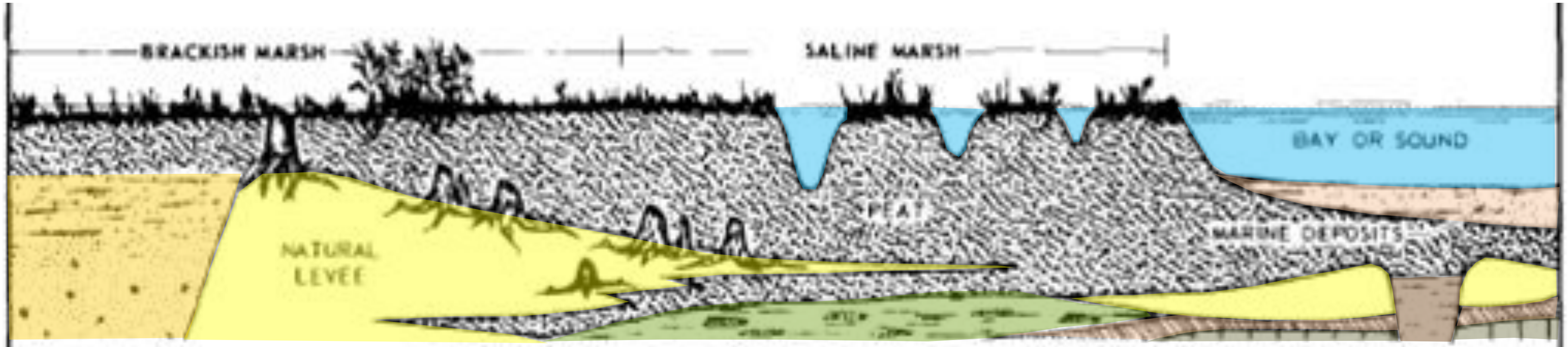
The Delta Cycle
natural evolution of the wetlands



There are indications that many avulsions of the river are not single catastrophic events, but may be gradual processes that span many decades. The onset of this process still means that the sediment supply to the delta being abandoned is reduced. In this early stage of abandonment the sediment supply is no longer capable of maintaining the elevation of the natural levee of the main channel. It is however adequate to sustain the elevation of the brackish marsh, which continues to expand in area as the volume of freshwater coming into the system is reduced. The progression of subsidence means that the accumulated peats are now the more significant component of the subsurface.

The Delta Cycle

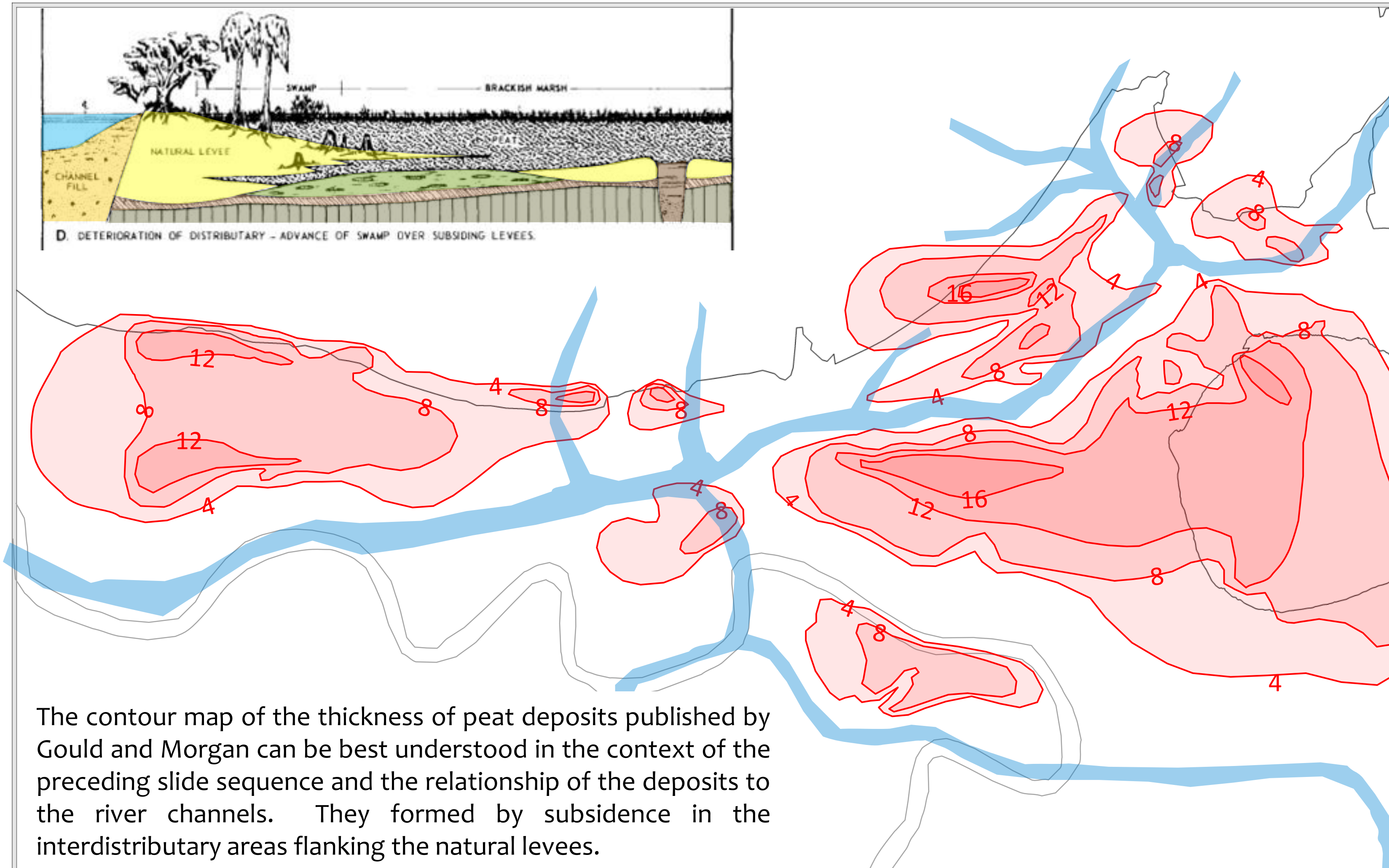
natural evolution of the wetlands



E. CONTINUED SUBSIDENCE WITH PARTIAL DESTRUCTION OF MARSHES.

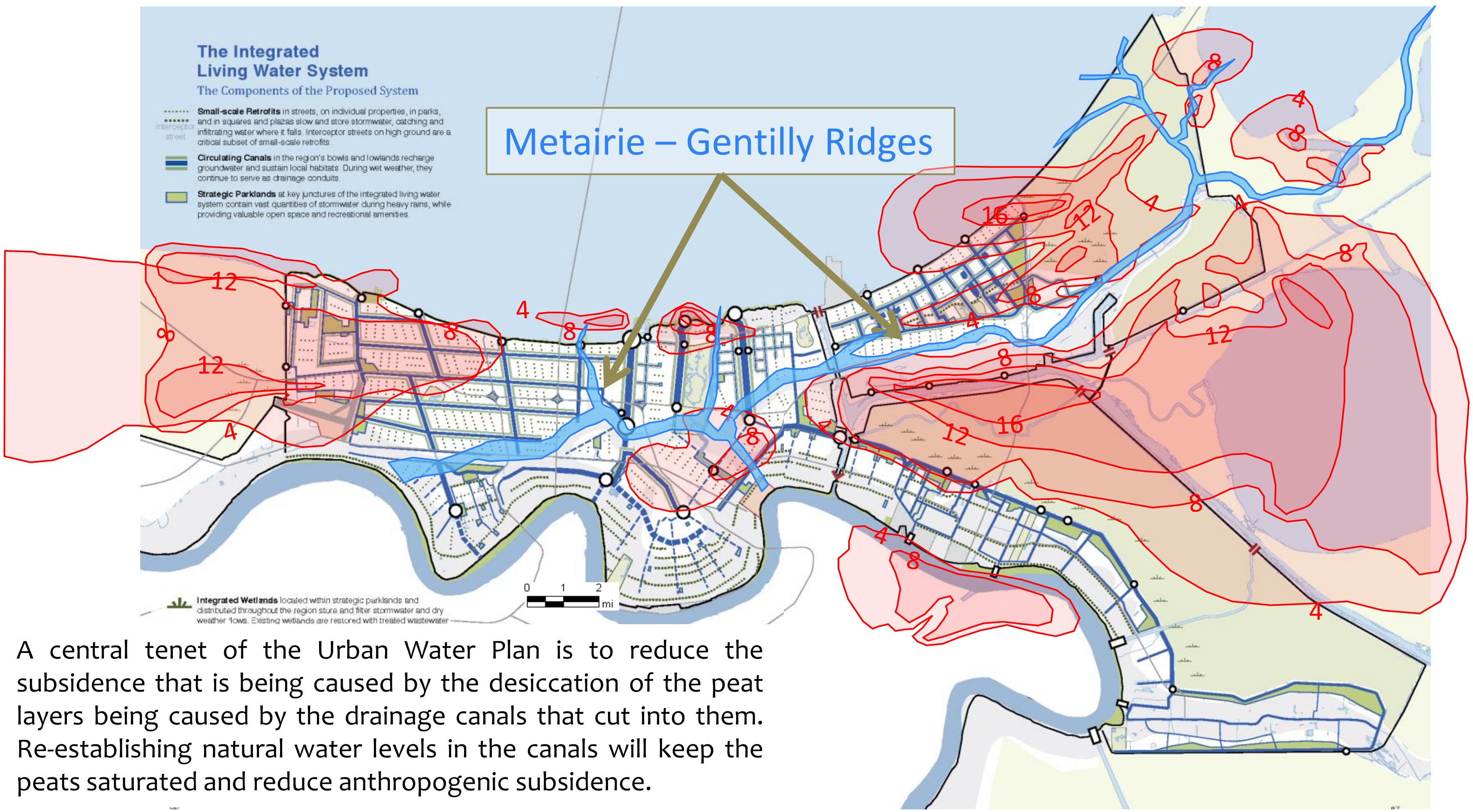
After complete abandonment all of the natural levee, freshwater swamp and freshwater marsh deposits have subsided below the surface. Brackish and saline marshes account for all of the wetlands, and they begin subsiding below the surface to from an open bay or sound. Eventually the entire area with revert to an open body of water until it is re-occupied by a new delta system, and the cycle will repeat. It is important to note in this sequence that saline and brackish marshes, which are the most biologically productive wetlands in terms of fisheries, are formed by the succession of ecosystems from fresh to saline that is driven by subsidence. It is generally not possible to create new saline marsh – it must be developed by this succession over several centuries.

Thickness of Peat



The contour map of the thickness of peat deposits published by Gould and Morgan can be best understood in the context of the preceding slide sequence and the relationship of the deposits to the river channels. They formed by subsidence in the interdistributary areas flanking the natural levees.

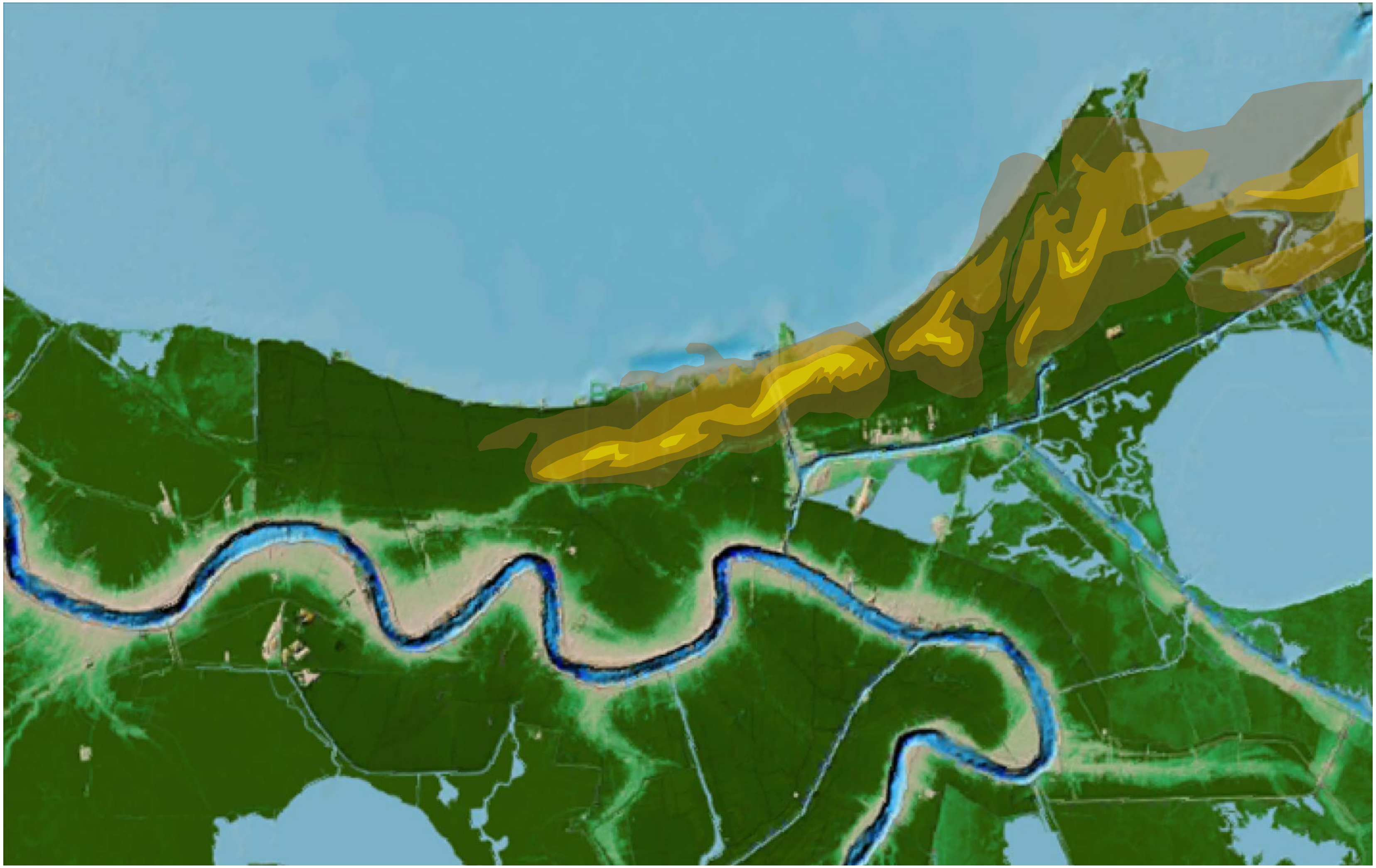
Thickness of Peat



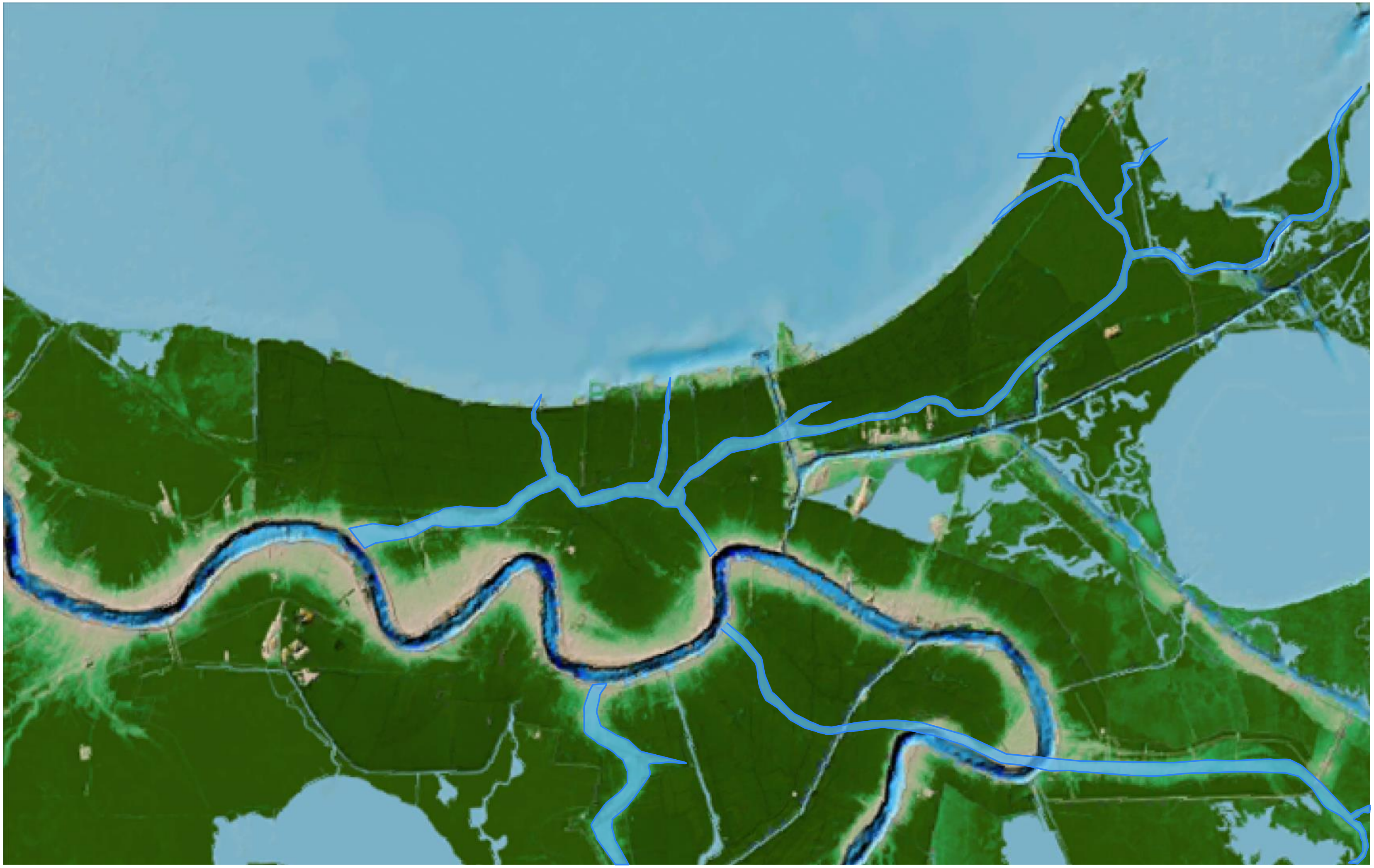
A central tenet of the Urban Water Plan is to reduce the subsidence that is being caused by the desiccation of the peat layers being caused by the drainage canals that cut into them. Re-establishing natural water levels in the canals will keep the peats saturated and reduce anthropogenic subsidence.

In this sequence the NOAA Digital Elevation Model is used as a base to consider the interrelationships between the barrier island deposits, the river channels, the thickness of the peat, and one measure of subsidence rates

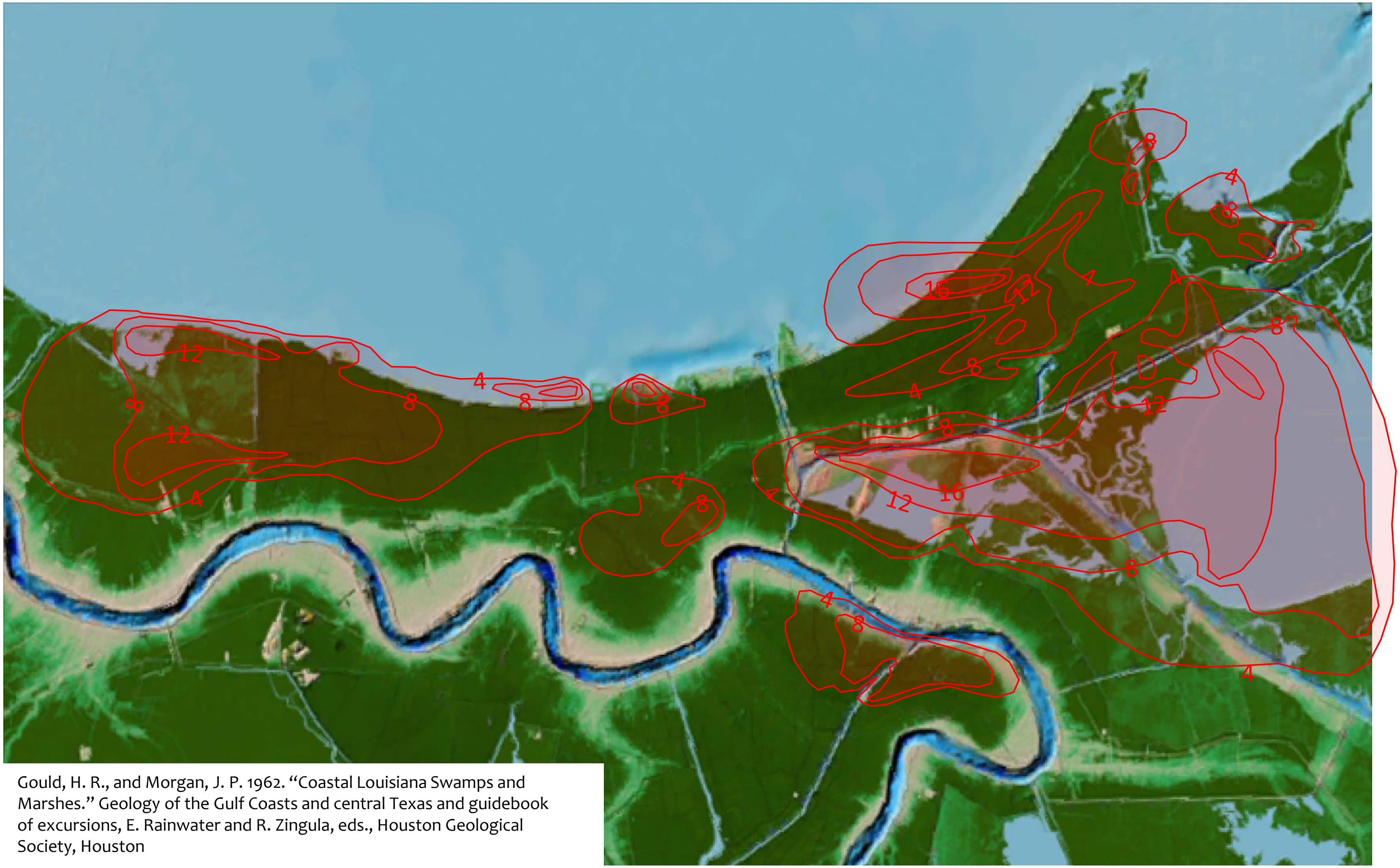
Depth of Pine Island Sand



Bayou Sauvage Channels

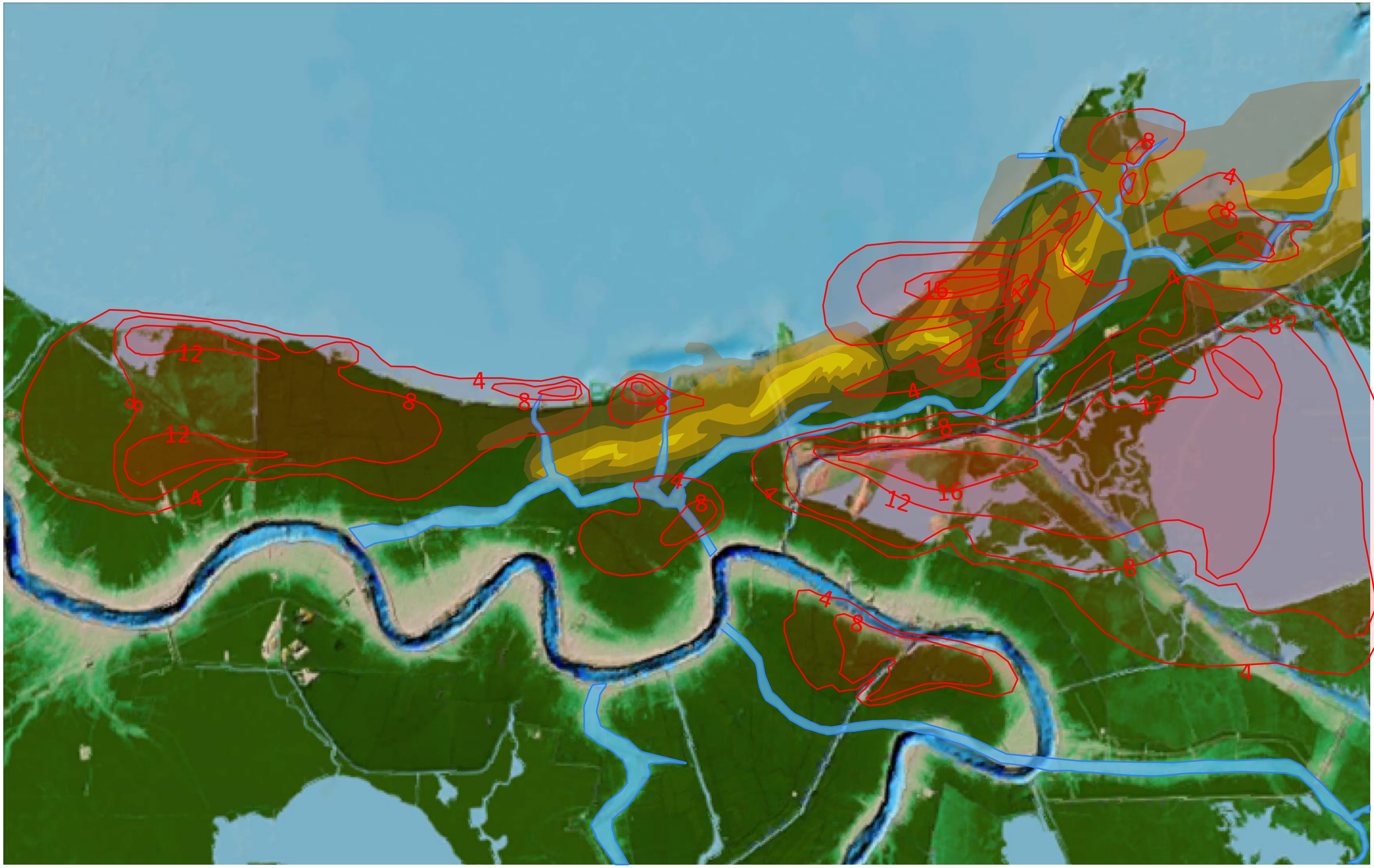


Thickness of Peat



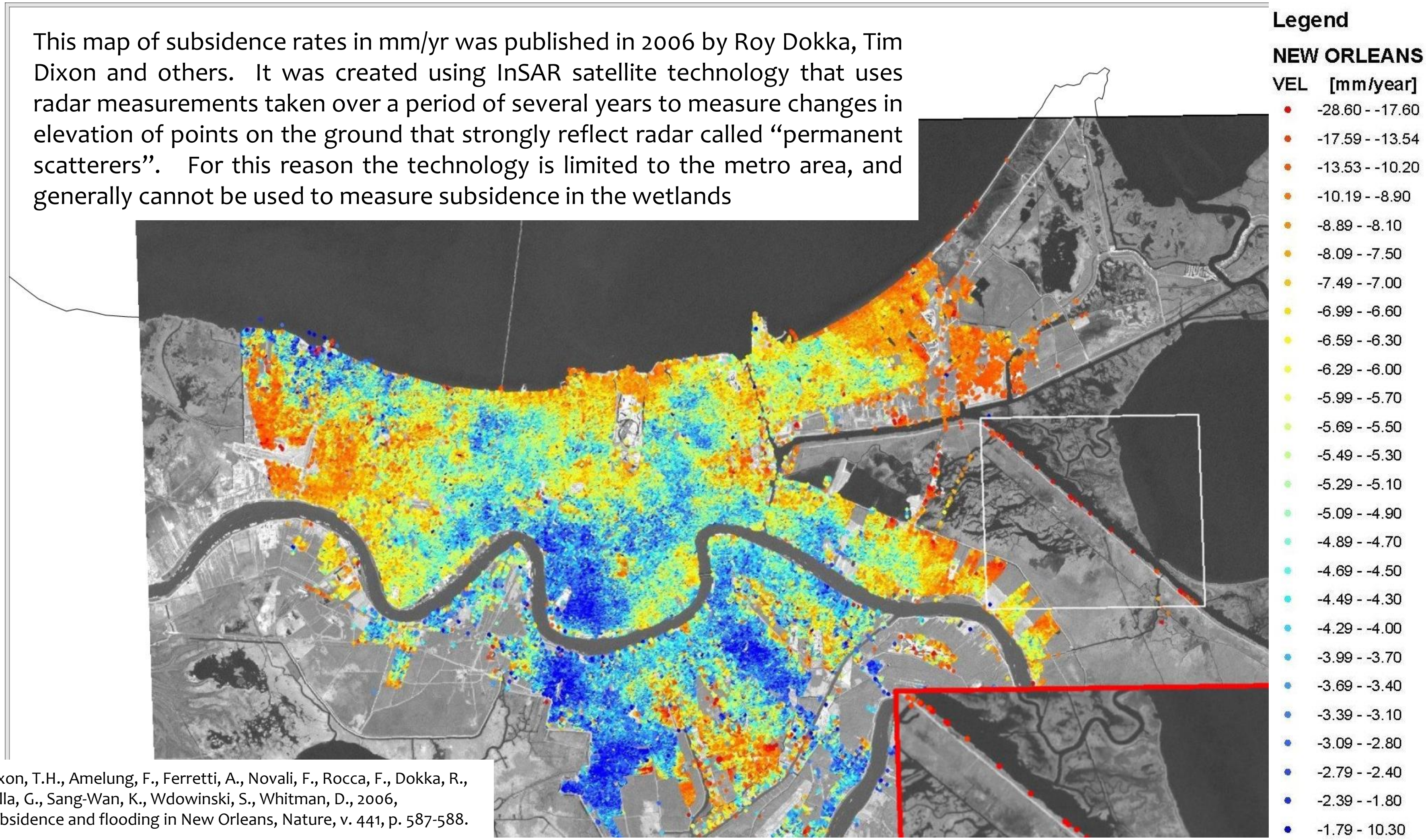
Gould, H. R., and Morgan, J. P. 1962. "Coastal Louisiana Swamps and Marshes." Geology of the Gulf Coasts and central Texas and guidebook of excursions, E. Rainwater and R. Zingula, eds., Houston Geological Society, Houston

Composite



Subsidence

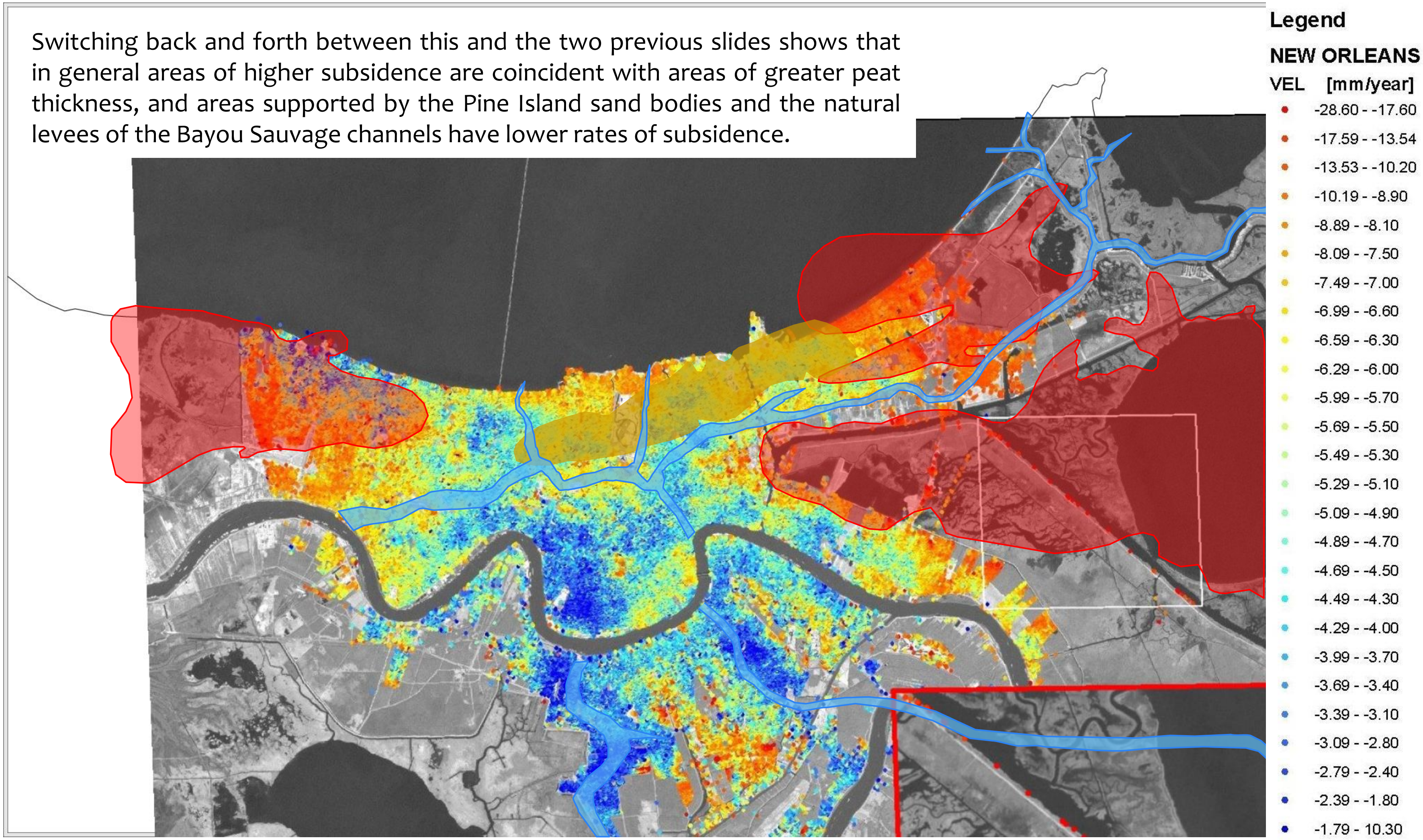
This map of subsidence rates in mm/yr was published in 2006 by Roy Dokka, Tim Dixon and others. It was created using InSAR satellite technology that uses radar measurements taken over a period of several years to measure changes in elevation of points on the ground that strongly reflect radar called "permanent scatterers". For this reason the technology is limited to the metro area, and generally cannot be used to measure subsidence in the wetlands



Dixon, T.H., Amelung, F., Ferretti, A., Novali, F., Rocca, F., Dokka, R., Sella, G., Sang-Wan, K., Wdowinski, S., Whitman, D., 2006, Subsidence and flooding in New Orleans, Nature, v. 441, p. 587-588.

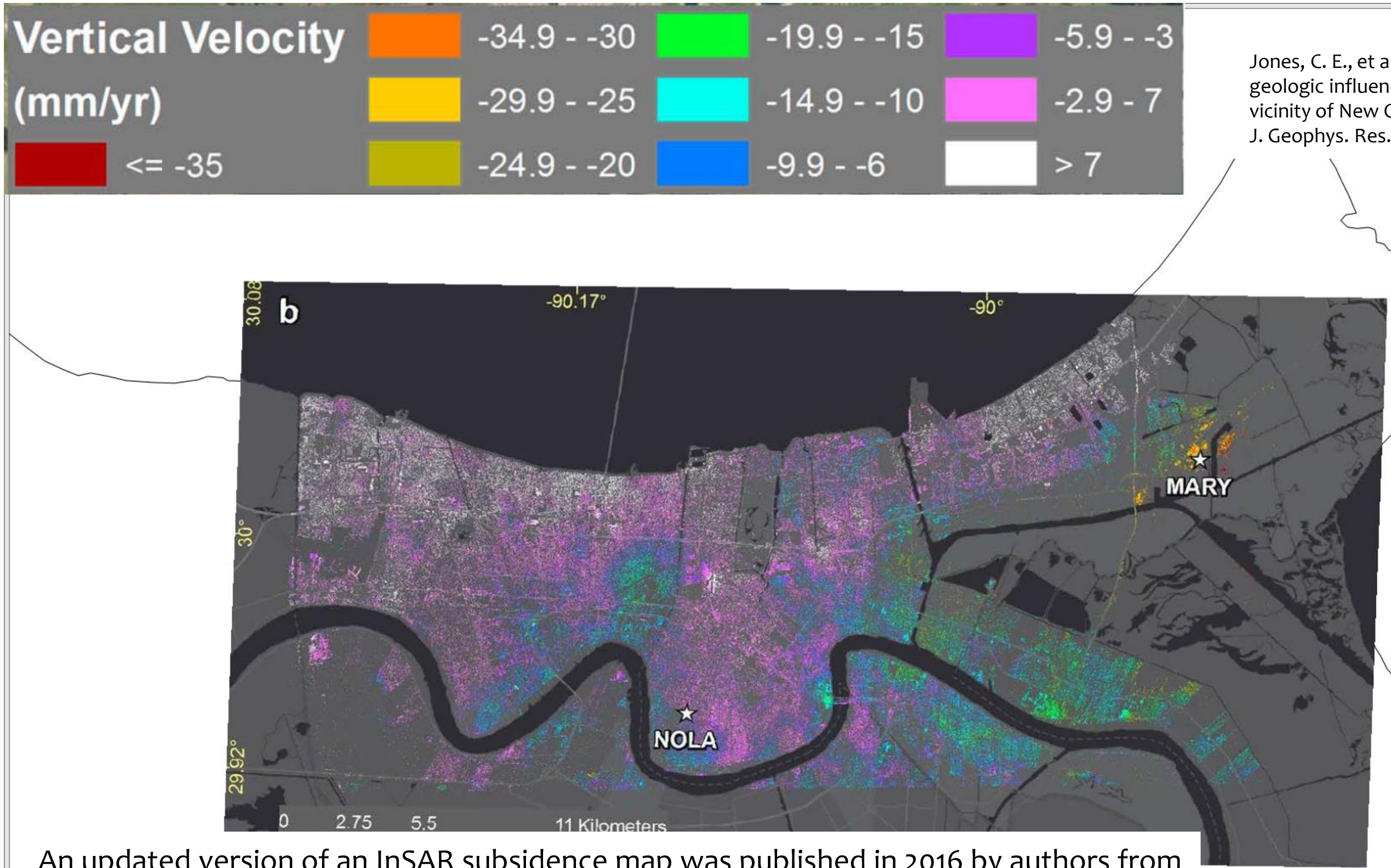
Subsidence

Switching back and forth between this and the two previous slides shows that in general areas of higher subsidence are coincident with areas of greater peat thickness, and areas supported by the Pine Island sand bodies and the natural levees of the Bayou Sauvage channels have lower rates of subsidence.



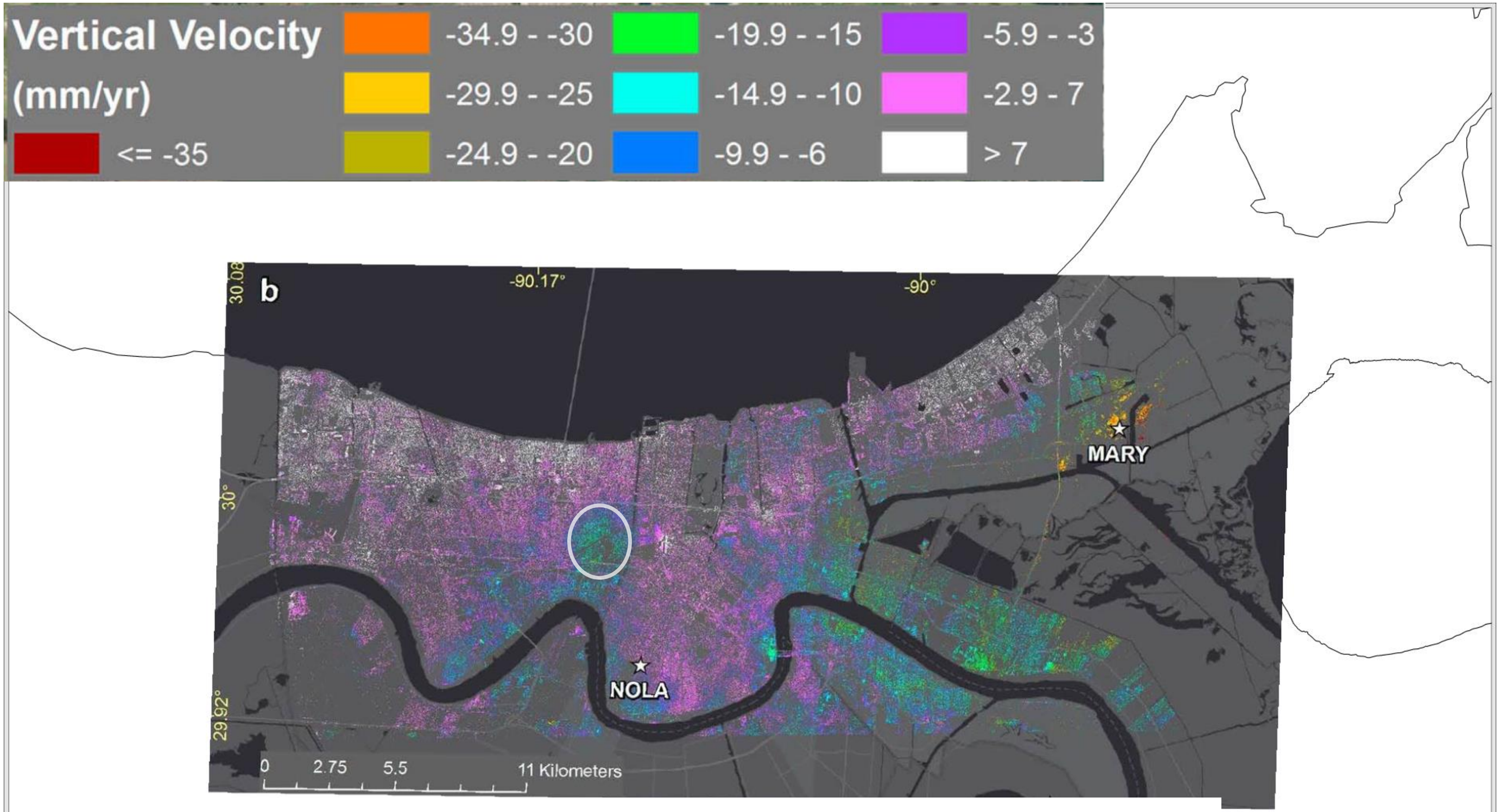
Subsidence

Jones, C. E., et al., 2016, Anthropogenic and geologic influences on subsidence in the vicinity of New Orleans, Louisiana
J. Geophys. Res. Solid Earth, v. 121, pgs. 2169-



An updated version of an InSAR subsidence map was published in 2016 by authors from the NASA Jet Propulsion Lab and the LSU Center for GeoInformatics. There are some differences from the earlier map, and interpretations of the rates and causes of subsidence will likely continue to evolve.

Subsidence



One of the significant findings of the 2016 subsidence evaluation was a distinct signature of an area of subsidence rates of 10-20 mm/yr at the white oval. This area is colloquially known as Hoey's Basin. A possible cause for this area of subsidence is considered here.

Hoey's Basin

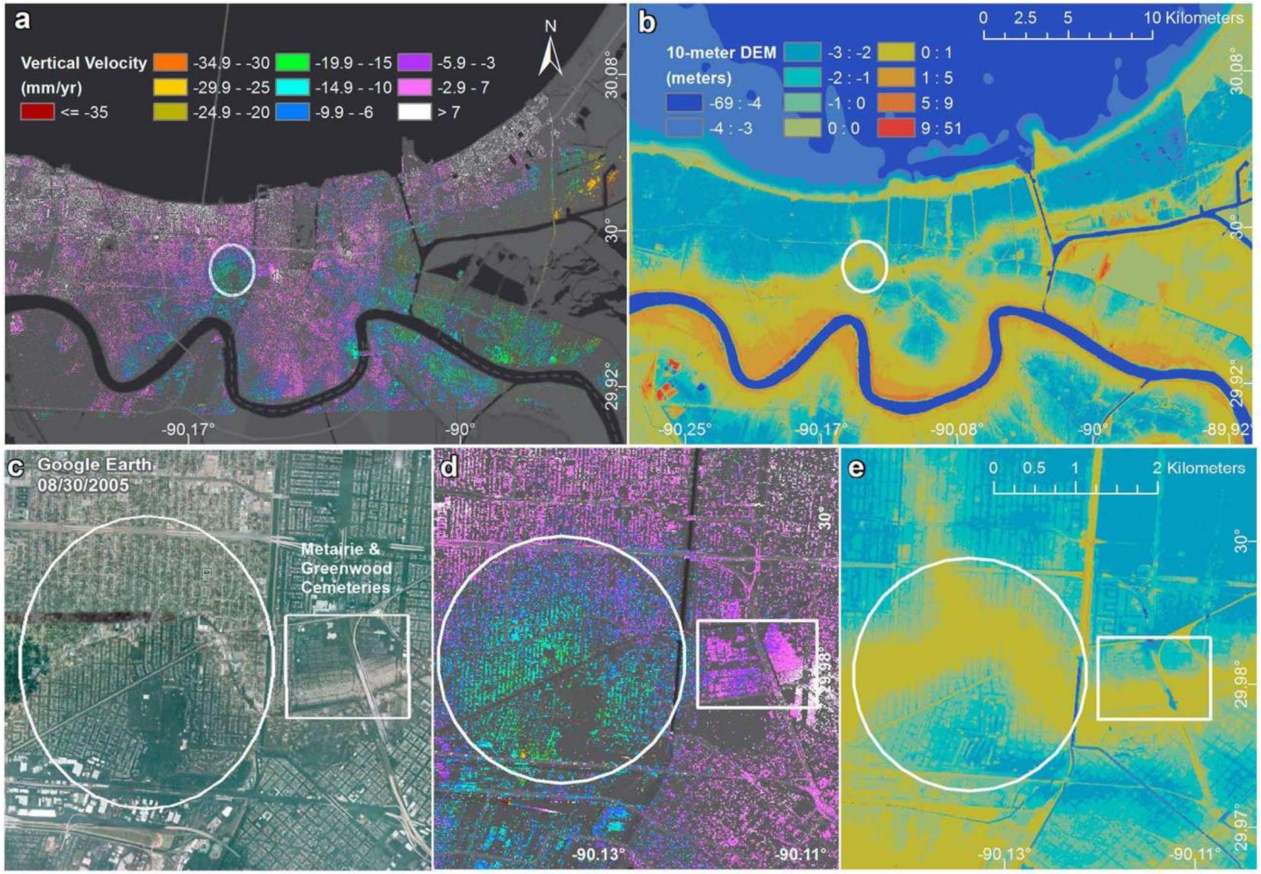
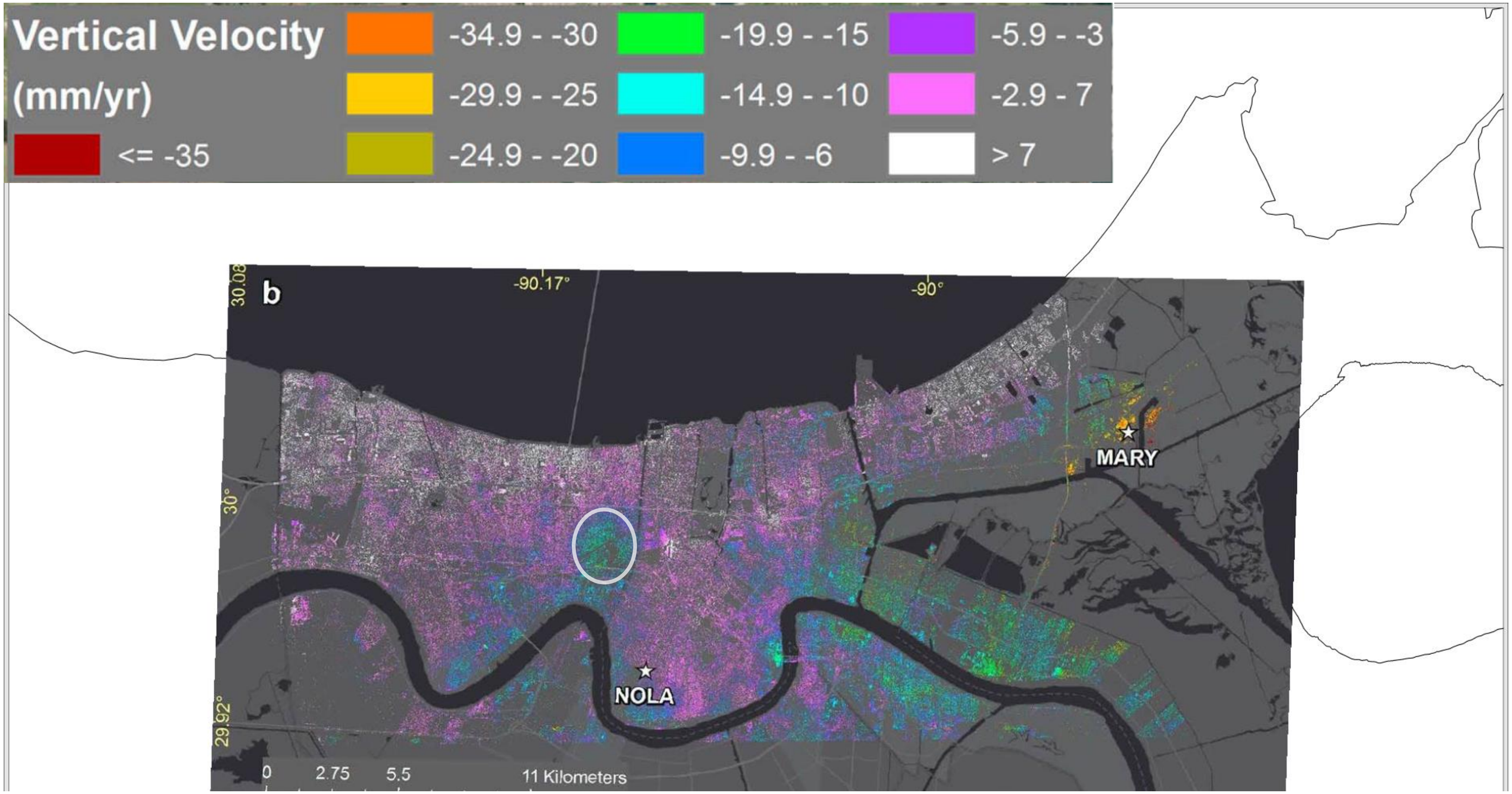


Figure 7. (a) Overview of subsidence with (d) a close-up of an area in Metairie showing subsidence. The subsidence feature in Metairie is a white outlined circle on all maps and images. (b) Elevations of the full and (e) close-up area in Figures 7a and 7d. The subsidence does not follow elevation strictly but does include a low area (locally the low elevation point) nearly encircled by higher-elevation land. (c) Optical image showing flooding from Hurricane Katrina on 30 August 2005 near the east side of Metairie, including flooding of the Metairie and Greenwood cemeteries (white outlined box). The areas at the northeast were not flooded but to the west and south were inundated to varying depths (Hurricane Katrina flood depth shown in Figure 6b). (Image credit: Google Earth) Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, ©OpenStreetMap contributors, and the GIS user community.

Subsidence



Comparing this and the next slide suggests a possible cause for the subsidence rates in the Hoey's Basin area. The topography of the Pleistocene surface indicates that the area is underlain by an erosional channel cut into the Pleistocene. The later infilling of this topography with more compactable Holocene sediments may have resulted in high rates of compaction in this area. This possibility has not been considered by peer-reviewed academic research and is only offered here as a suggestion.

Pleistocene Surface

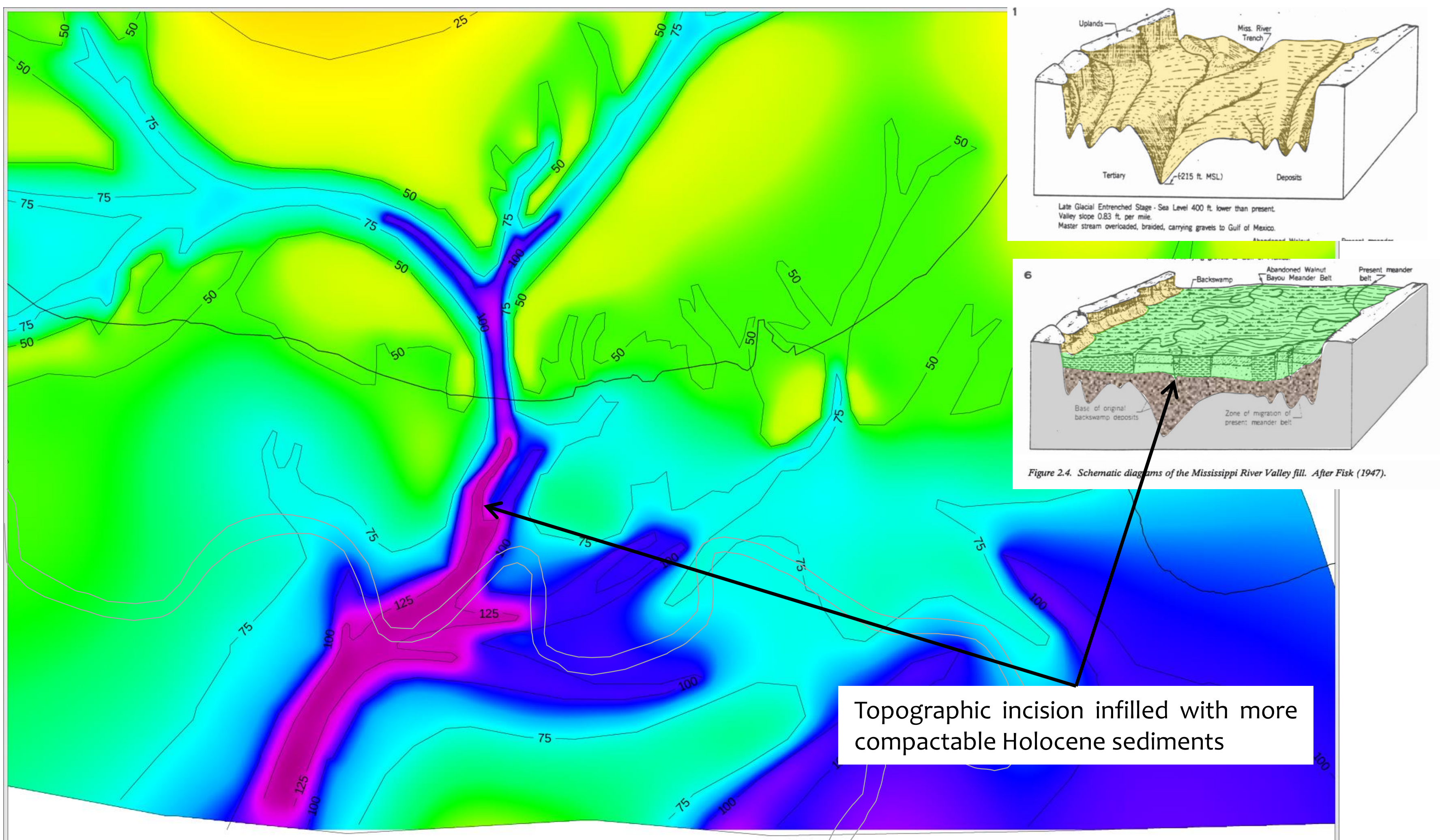
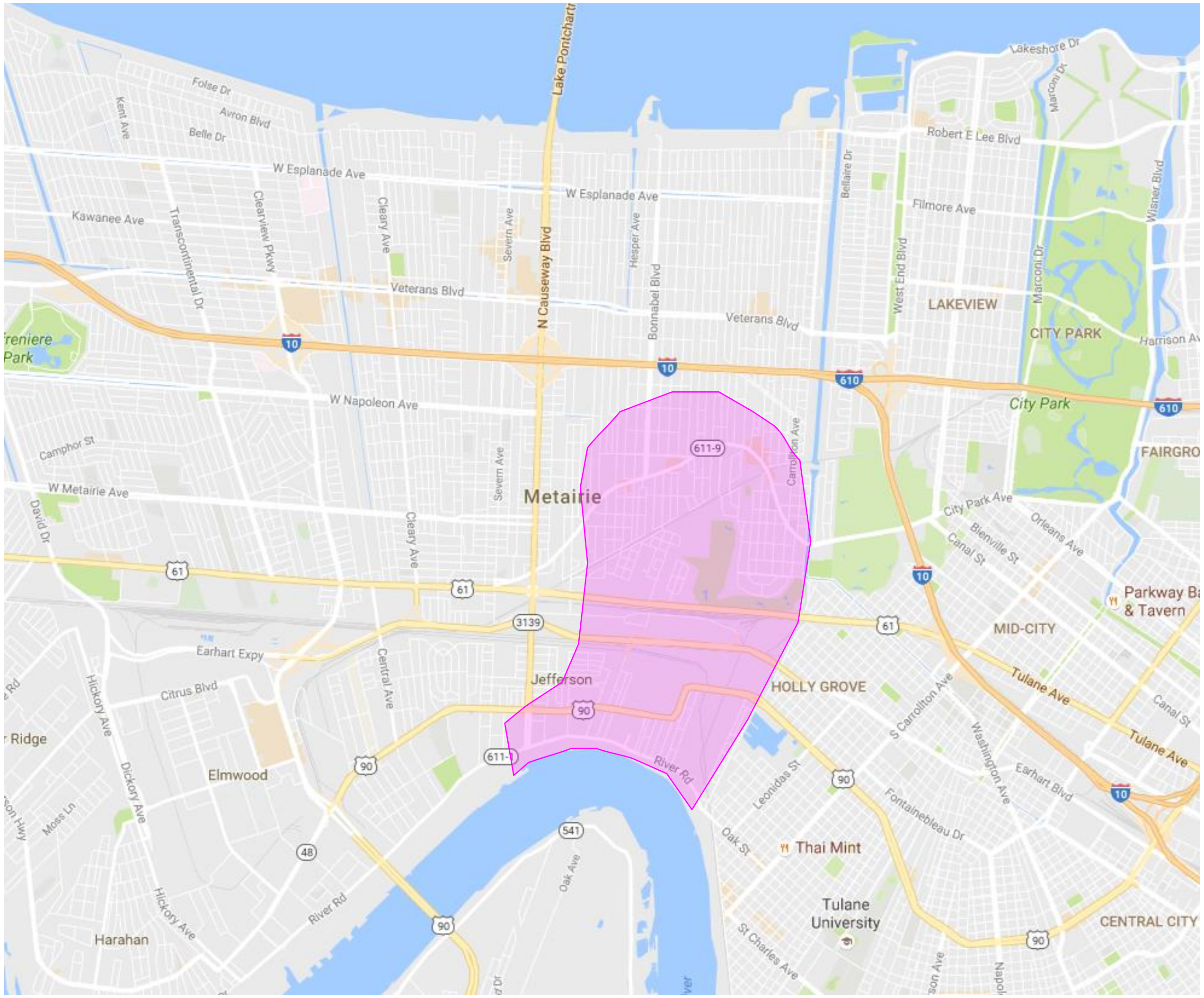


Figure 2.4. Schematic diagrams of the Mississippi River Valley fill. After Fisk (1947).

Topographic incision infilled with more compactable Holocene sediments

Hoey's Basin

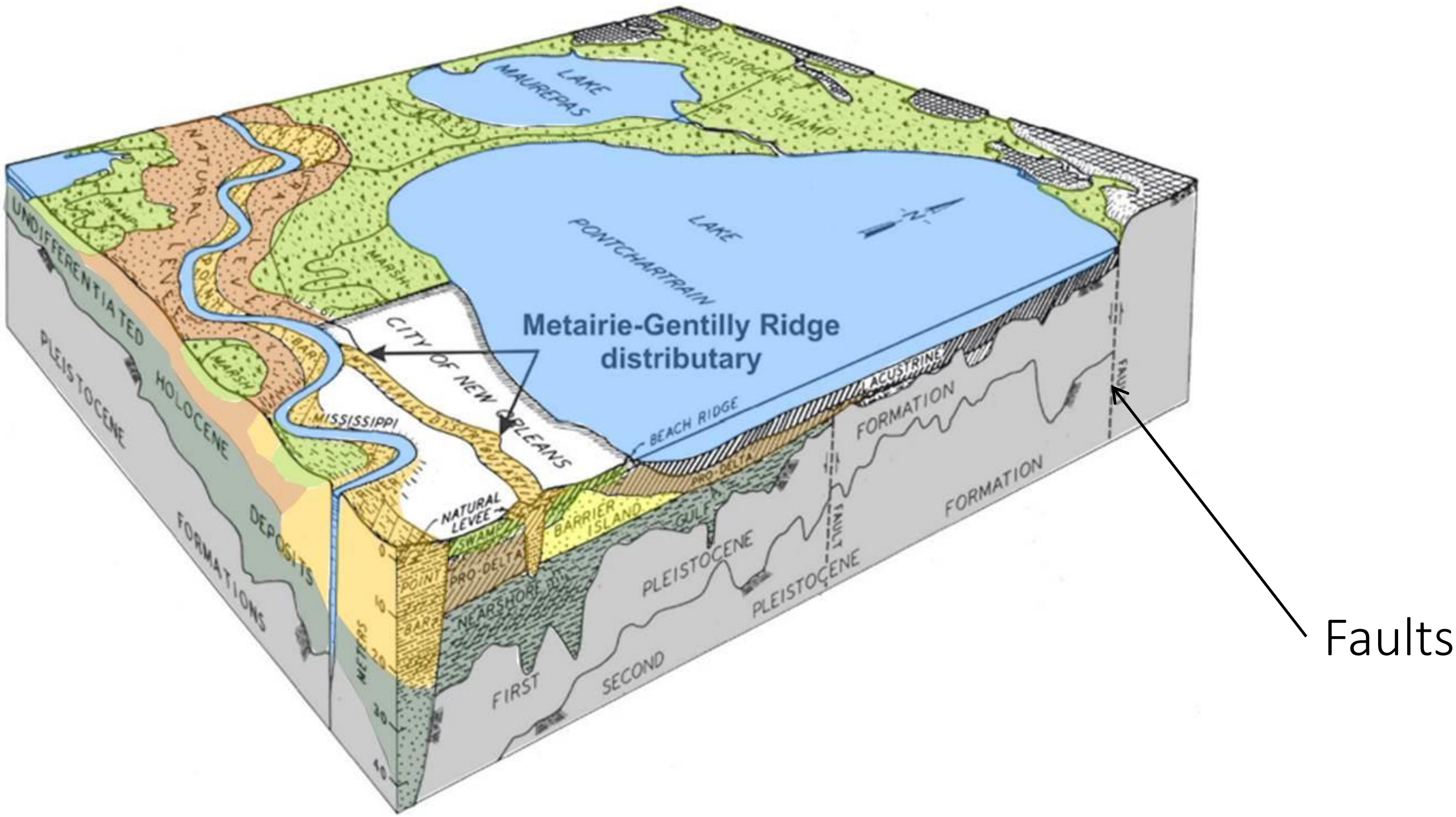


Metairie
Jefferson
LAKEVIEW
CITY PARK
City Park
MID-CITY
HOLLY GROVE
Elmwood
Harahan
Tulane University
CENTRAL CITY
Thai Mint
Parkway Bakery & Tavern
N Causeway Blvd
Lake Pontchartrain
Veterans Blvd
W Esplanade Ave
W Napoleon Ave
W Metairie Ave
Earhart Expy
Citrus Blvd
River Rd
Tulane Ave
Canal St
Robert E Lee Blvd
Filmore Ave
West End Blvd
Bonnabel Blvd
Clearview Pkwy
Transcontinental Dr
Kawanee Ave
Cleary Ave
Severn Ave
Hesper Ave
Central Ave
Hickory Ave
Dickory Ave
S Carrollton Ave
Washington Ave
Earhart Blvd
Fontainebleau Dr
Leonidas St
Oak St
St Charles Ave
City Park Ave
Orleans Ave
Bienville St
Lakeshore Dr
Harrison Ave
Camphor St
David Dr
Folse Dr
Avron Blvd
Belle Dr
Kent Ave
Marconi Dr
Wisner Blvd
Bellaire Dr
Oak Ave
Moss Ln

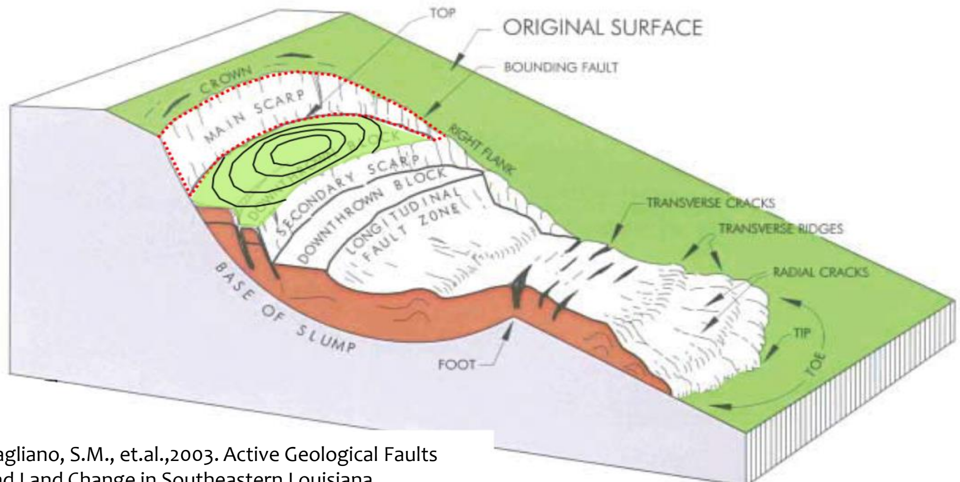
New Orleans

below the surface

The final of the essential elements of the shallow subsurface geology of New Orleans to be considered is the geologic fault.

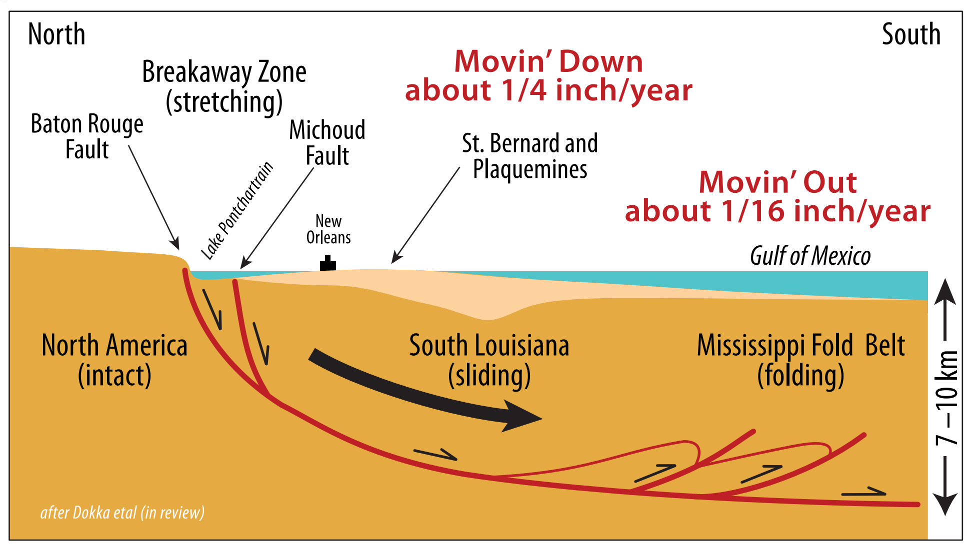


What is a Fault?



Gagliano, S.M., et.al.,2003. Active Geological Faults and Land Change in Southeastern Louisiana. Prepared for U.S. Army Corps of Engineers, New Orleans District, Contract No. DACW 29-00-C-0034

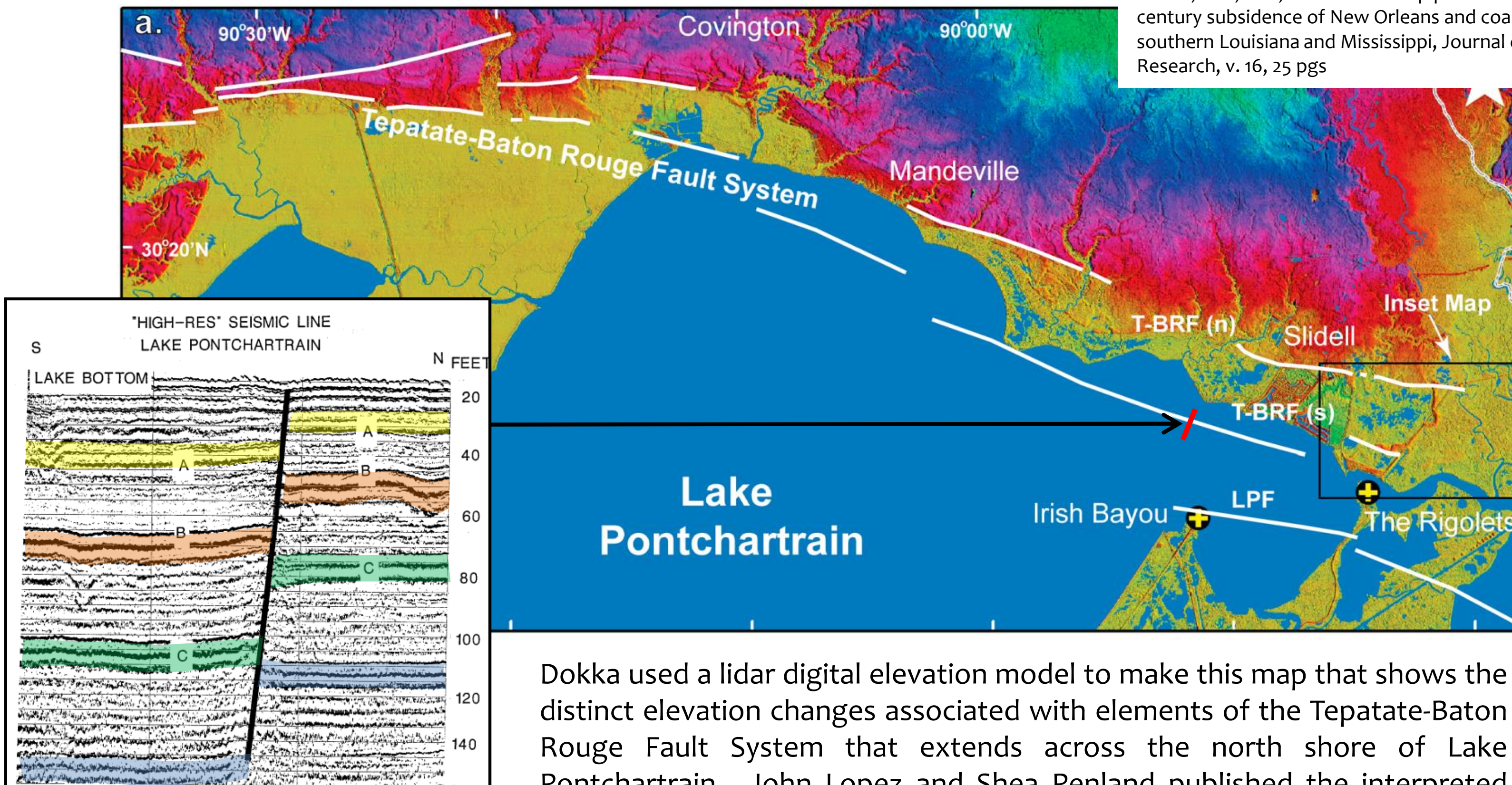
The basic elements of the geologic fault are similar to those of its geomorphic cousin, the landslide, as shown in the block diagram to the left constructed by Gagliano. These include a slide surface labelled "base of slump" along which the earth materials in the downthrown block move. Fault movement creates an escarpment labelled "main scarp" that generally causes a change in elevation at the earth's surface where the fault is active. Dokka created the diagram below to make clear the magnitude of scale of south Louisiana faults, which may cut thousands of feet below the surface and extend for miles laterally.



Dokka, R.K., 2011, The role of deep processes in late 20th century subsidence of New Orleans and coastal areas of southern Louisiana and Mississippi, Journal of Geophysical Research, v. 16, 25 pgs

Faulting and Subsidence

Dokka, R.K., 2011, The role of deep processes in late 20th century subsidence of New Orleans and coastal areas of southern Louisiana and Mississippi, Journal of Geophysical Research, v. 16, 25 pgs



Lopez, J.A., Penland, S. and Williams, J., 1997, Confirmation of Active Geologic Faults in Lake Pontchartrain in Southeast Louisiana, Trans. G.C.A.G.S., v. 47, p. 299-303

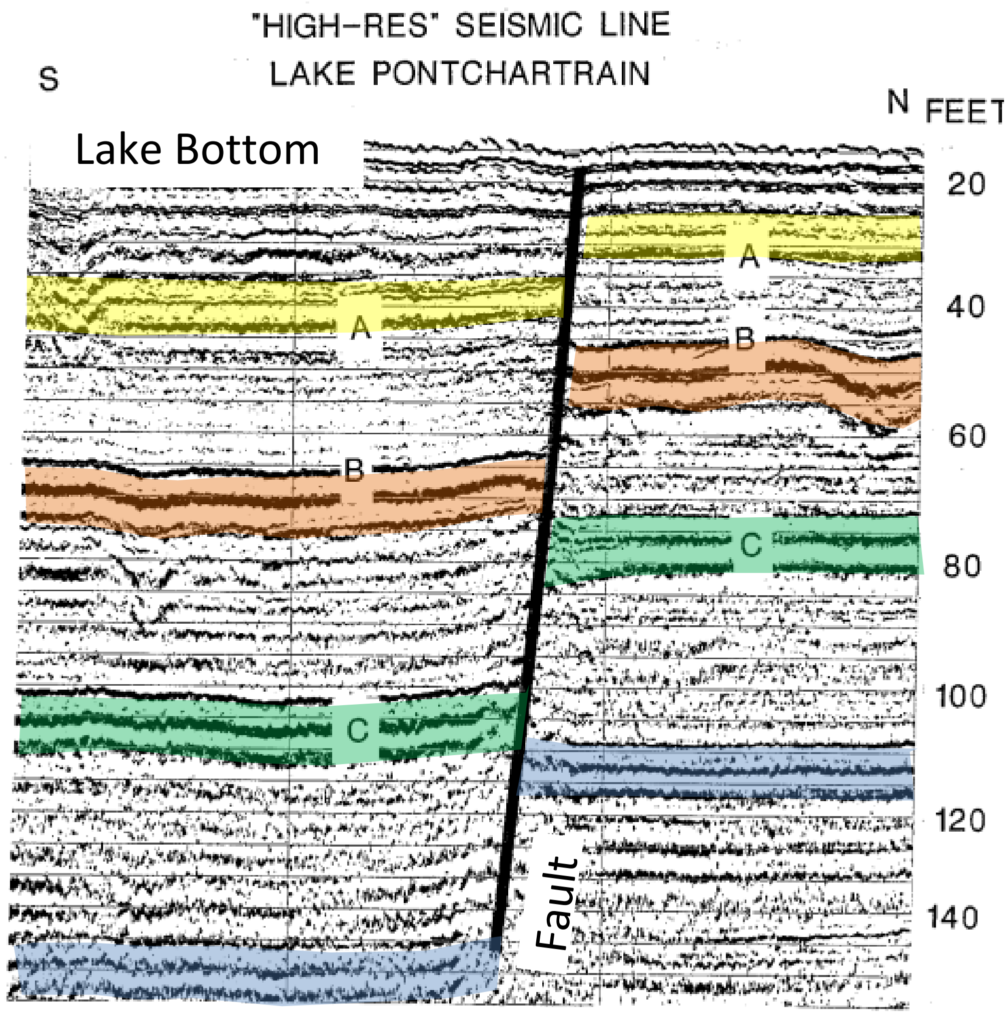
Dokka used a lidar digital elevation model to make this map that shows the distinct elevation changes associated with elements of the Tepatate-Baton Rouge Fault System that extends across the north shore of Lake Pontchartrain. John Lopez and Shea Penland published the interpreted USGS seismic line at the left showing one of these faults offsetting sedimentary layers beneath the lake at the location of the red line.

Faulting and Subsidence

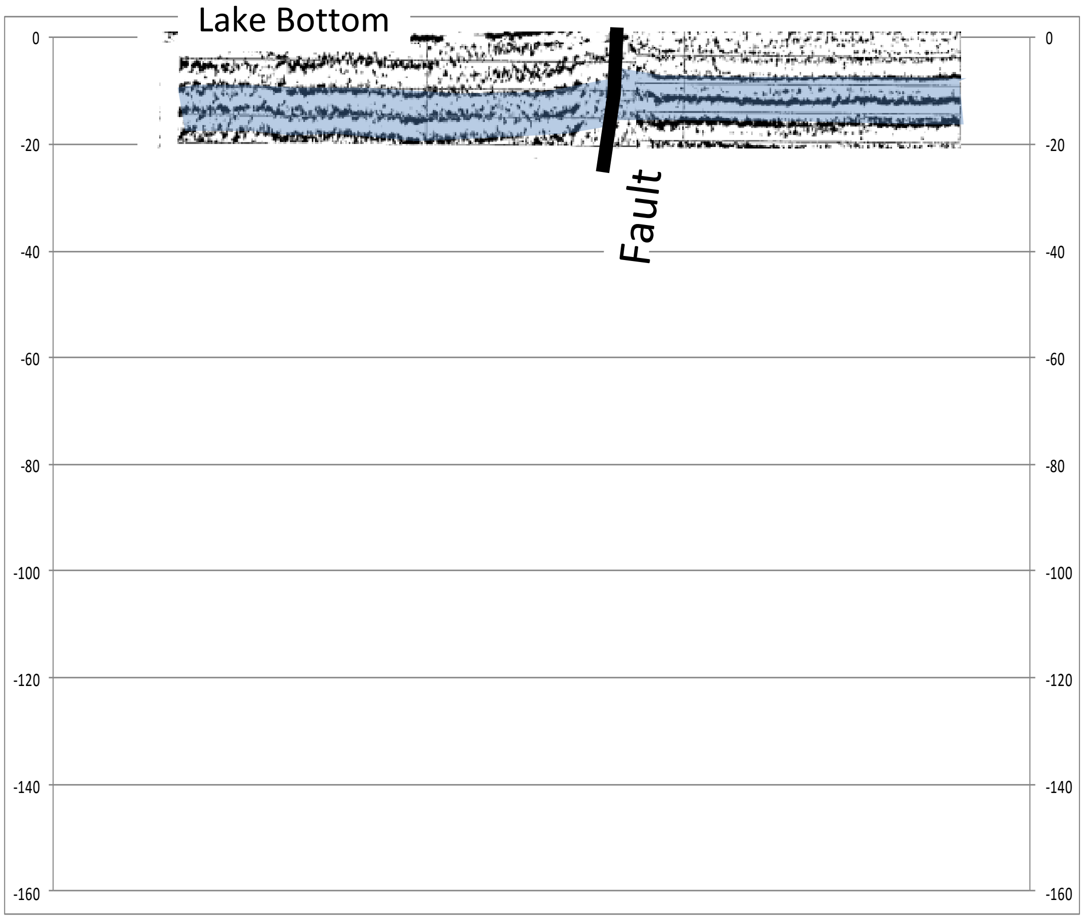
The following sequence of slides attempts to reconstruct the historical movement of this fault by restoring each of the colored seismic reflectors that represent sedimentary layers to a time immediately after its deposition when it was near the surface.

As deposition of sediments proceeds contemporaneously with movement on the fault, it is clear that the downthrown side of the fault is providing more accommodation space for sediment accumulation. This results in a greater thickness of compactable sediments on the downthrown side, and makes it a probable location for accelerated rates of subsidence.

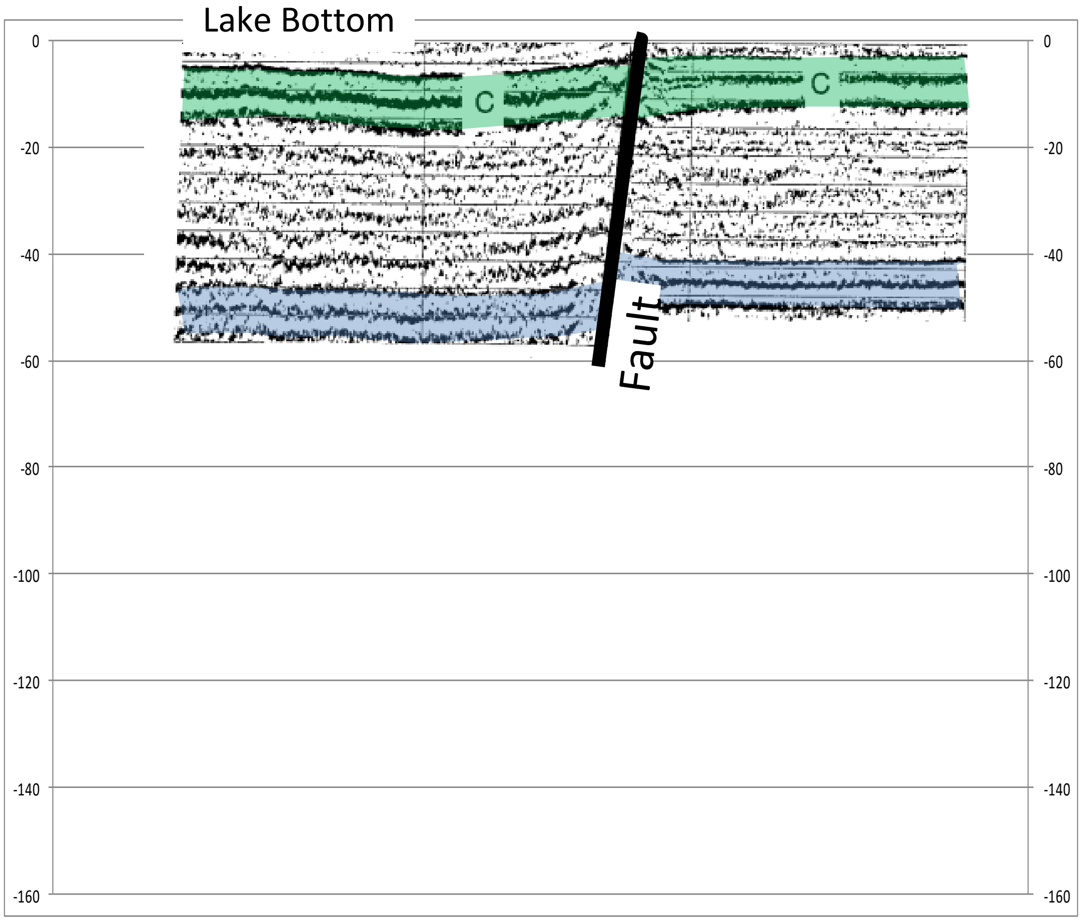
The rate of relative movement of the downthrown block is cumulative over time so the vertical offset of each sedimentary layer increases with depth. This is the phenomenon known as "growth faulting"



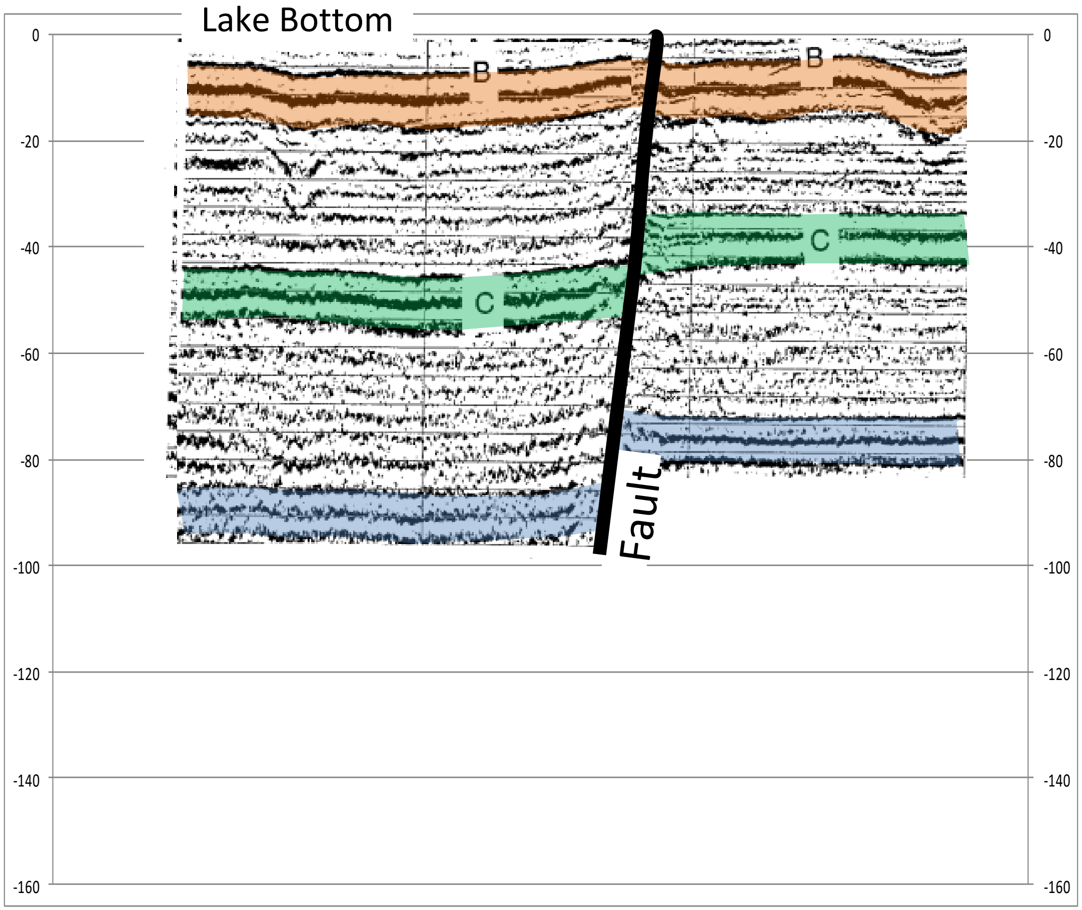
Faulting and Subsidence



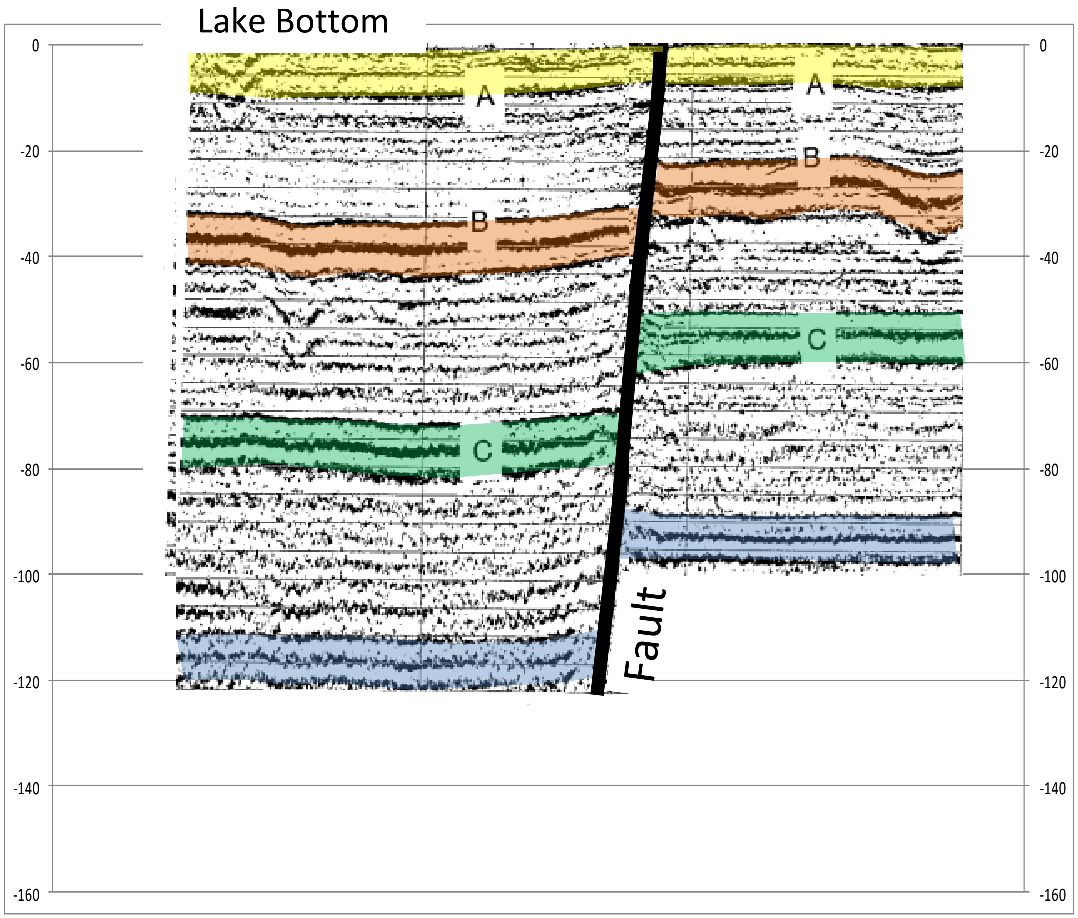
Faulting and Subsidence



Faulting and Subsidence

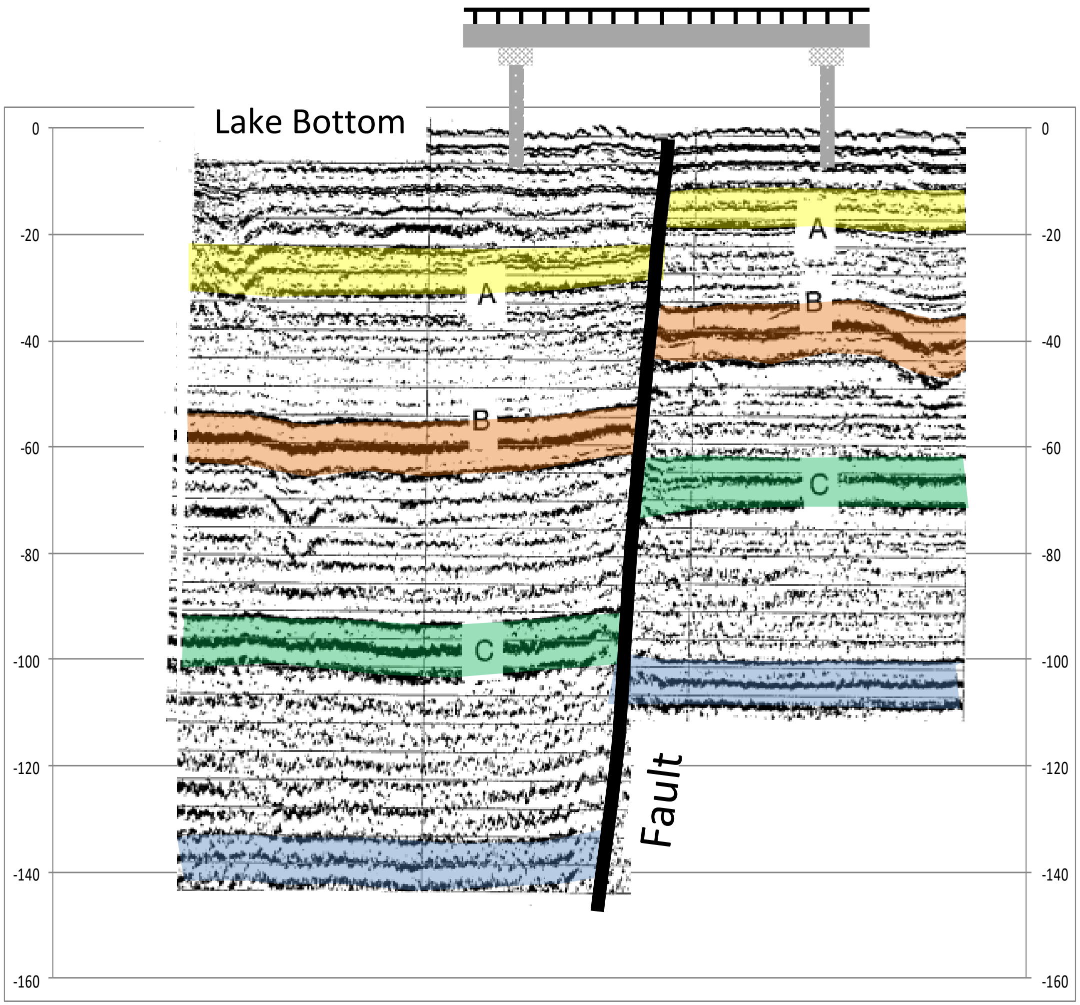


Faulting and Subsidence



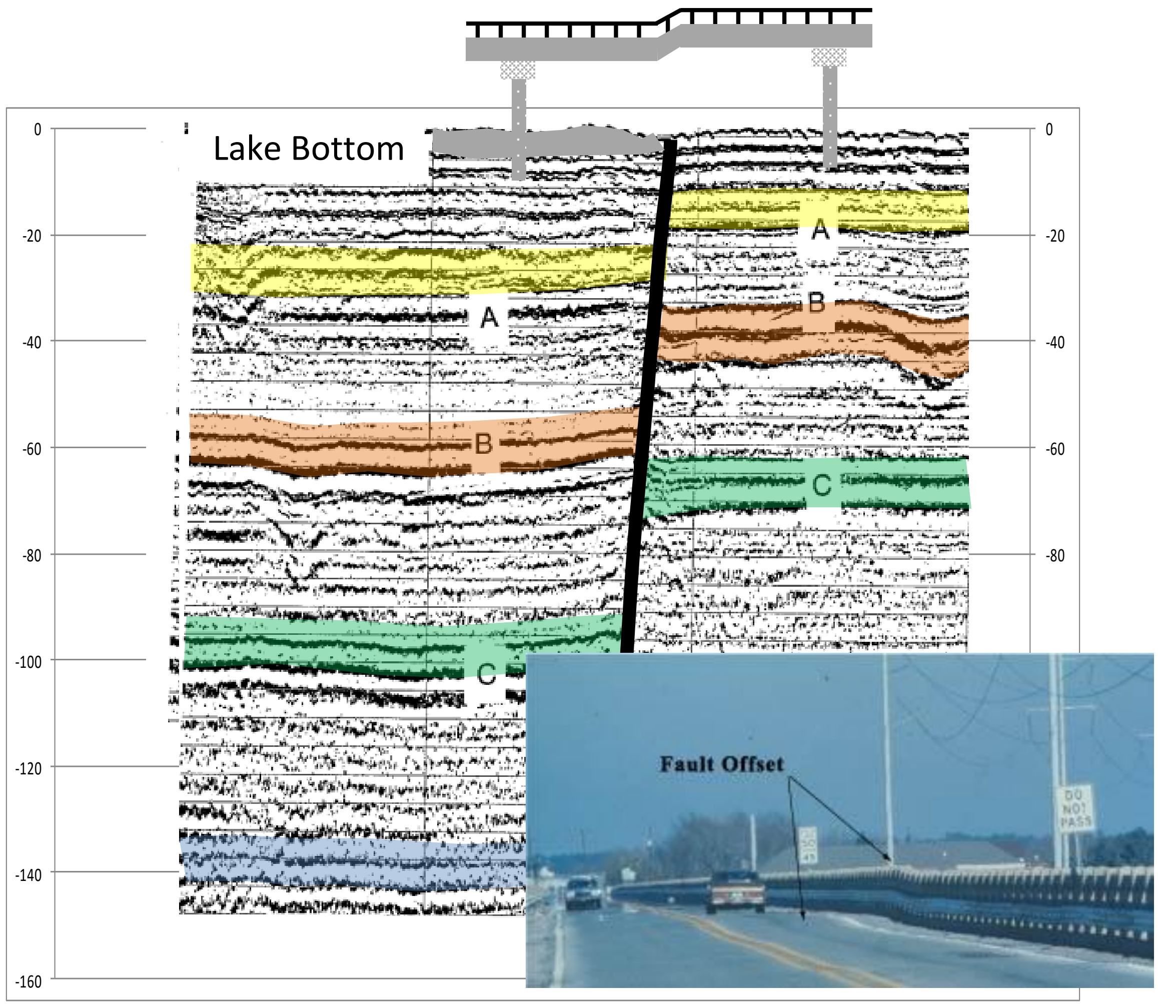
Faulting and Subsidence

The potential impact of active fault movement of surface infrastructure is perfectly illustrated by this fault because it crosses the La. Hwy. 11 bridge across Lake Pontchartrain at the location of the red line on the map.

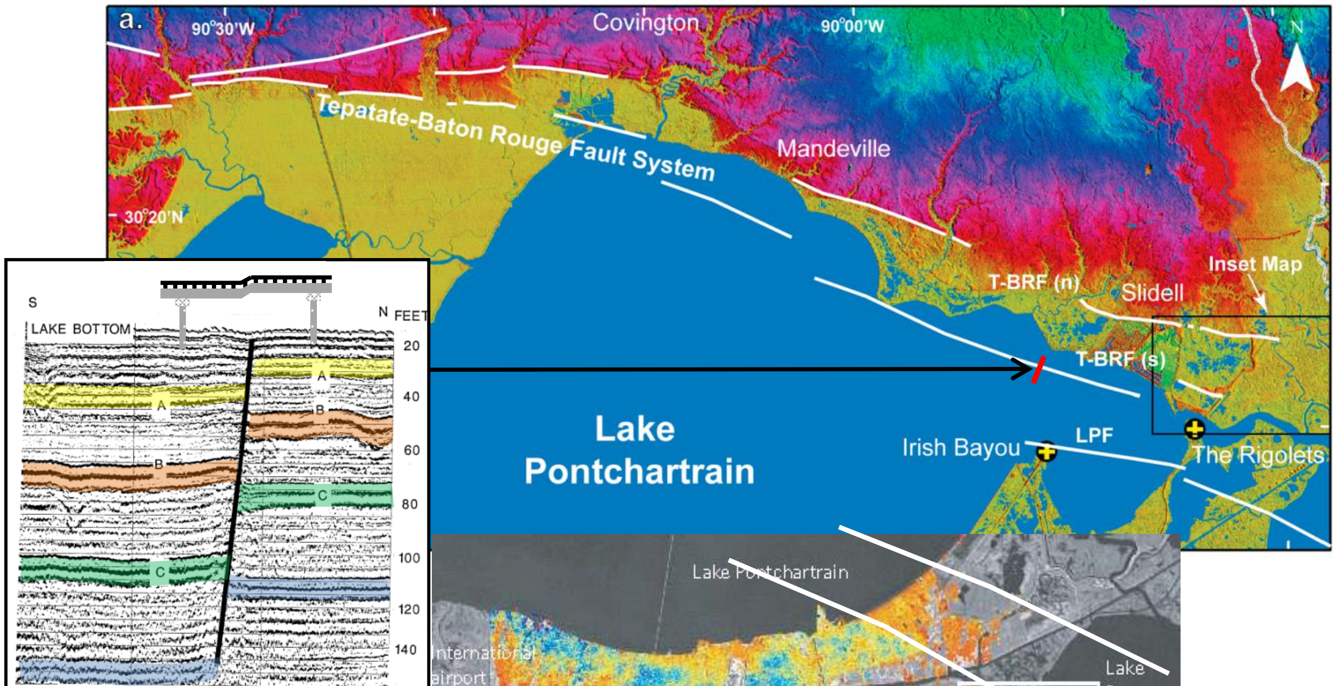


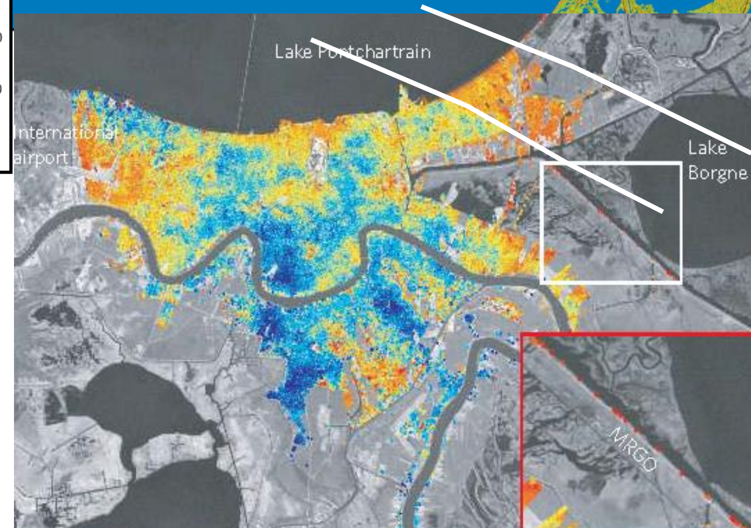
Faulting and Subsidence

Lopez and Penland documented the relationship between this fault and the obvious offset of the roadbed and gaurdrail on the La. Hwy. 11 bridge. They used this to estimate a rate of vertical movement of about 2.5 mm/yr.



Faulting and Subsidence





Dokka postulated the existence of two more faults crossing the New Orleans East Land Bridge parallel to those revealed by lidar elevation. His interpretation was based on lineations seen in the InSAR subsidence data. These lineations were not substantiated by the 2016 study, and will require more evaluation to definitively confirm. They are considered here based on Dokka's interpretation.

Mapping Faults

The most effective means of mapping faults in the subsurface is with seismic data. The seismic profile used by Lopez and Penland at the Hwy. 11 bridge was acquired by the USGS as a part of a broad geological assessment of Lake Pontchartrain.

The most expansive seismic coverage in southeast Louisiana is in the collection 3-D seismic surveys acquired in the 1990s and early 2000s for oil and gas exploration. These surveys can also be used to map the shallow subsurface including faulting, but they were generally very expensive to acquire, and most academic institutions cannot afford to purchase data licenses for research.

The New Orleans Geological Society sponsored an initiative to provide donated research licenses to area universities in late 2015. Since then research projects using 3-D surveys to map shallow subsurface geology in coastal Louisiana have been undertaken at UNO, Tulane and UL. Peer-reviewed academic publications of the results of these projects should be coming out in the next few months.

Wednesday, January 13, 2016

UNO Lab Receives Funding, Scholarships and Data to Support Sea Level Rise Research

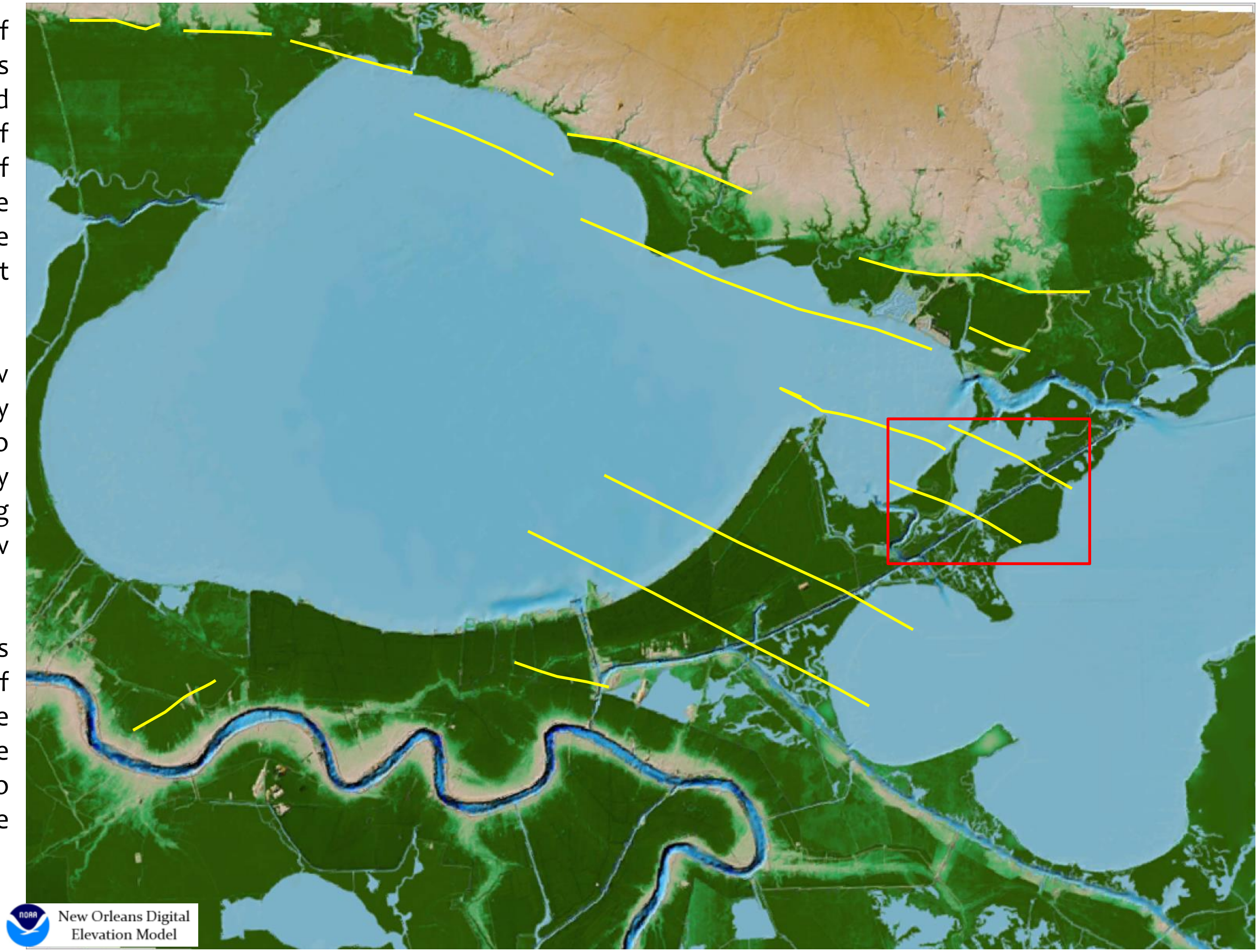
The University of New Orleans' Coastal Research Laboratory has received research funding, scholarship money and data from several companies and professional societies affiliated with the oil and gas industry. The donations will be applied to research projects, under an initiative of the New Orleans Geological Society, to study the impacts of relative sea level rise on Louisiana's coast.

Mapping Faults

The map at the right shows all of the possible surface fault traces that are indicated by published literature or by other means of evaluation. With the exception of the Hwy. 11 fault, these traces are not currently supported by the interpretation of seismic data that can be presented here.

It is an objective of the New Orleans Geological Society Research initiative to continue to expand the scope of university research projects that are utilizing 3-D seismic data to map shallow subsurface faulting.

The following sequence of slides will consider the indications of these faults, beginning with the two faults in the red box. Future research will be required to definitively determine the existence of these and others.



Mapping Faults

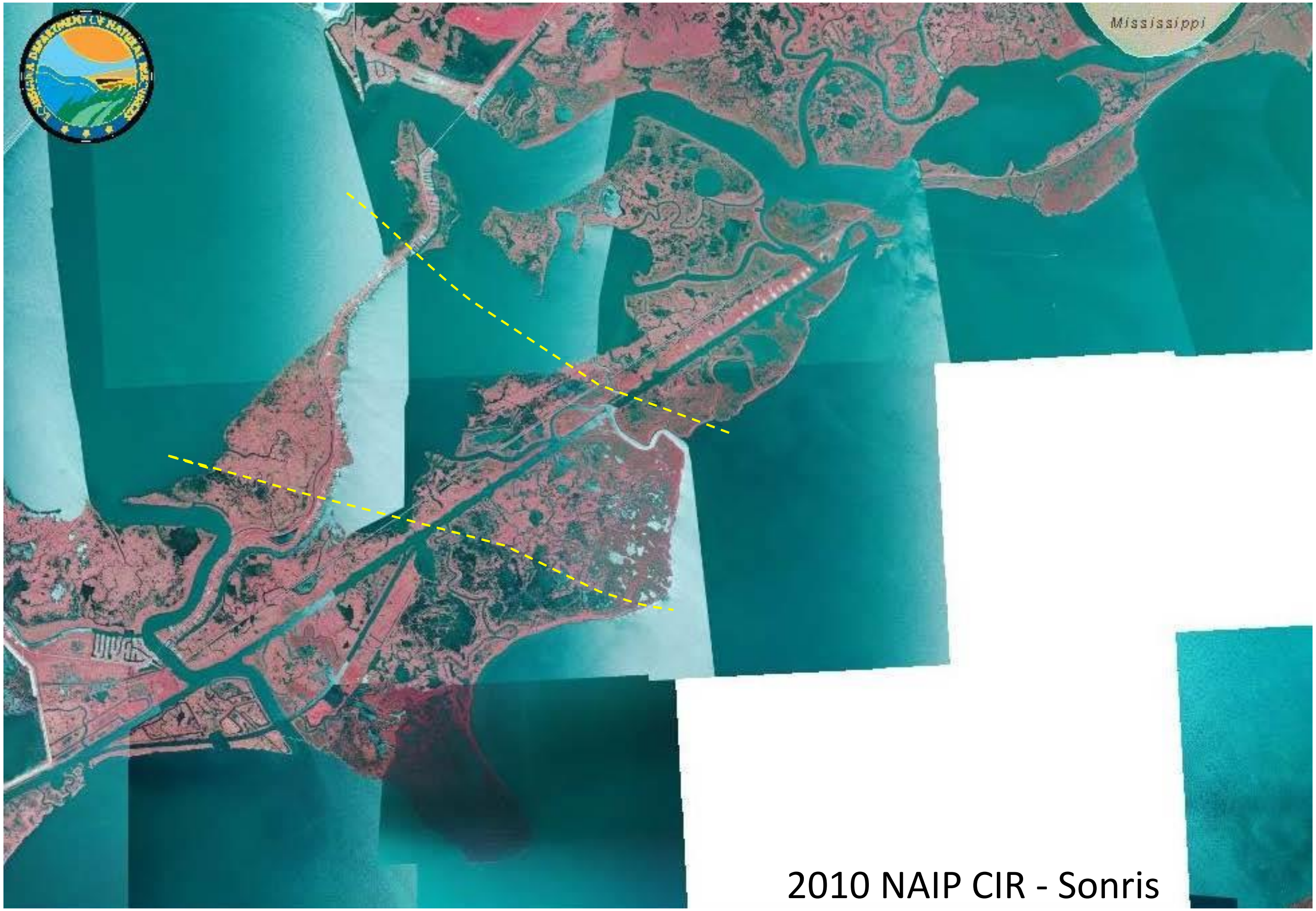
This and the two following maps show evidence of patterns of land loss that occurred during Hurricane Katrina being consistent with a possible relationship to two faults shown as dashed yellow lines. These lines are parallel to faults mapped to the Hwy. 11 fault and to faults suggested by Dokka based on subsidence signature.

It is suggested here that while this land loss was caused by the erosive forces of the Hurricane on the marsh grasses, the pattern indicates a relationship to the faults.

Mapping Faults

This and the previous slide are from the aerial photography collection available on the LaDNR Sonris website. Comparing these two photographs with the map on the next slide shows that areas of land loss in the marsh during Katrina were bounded on their north sides by the sharp lineations of the proposed faults.

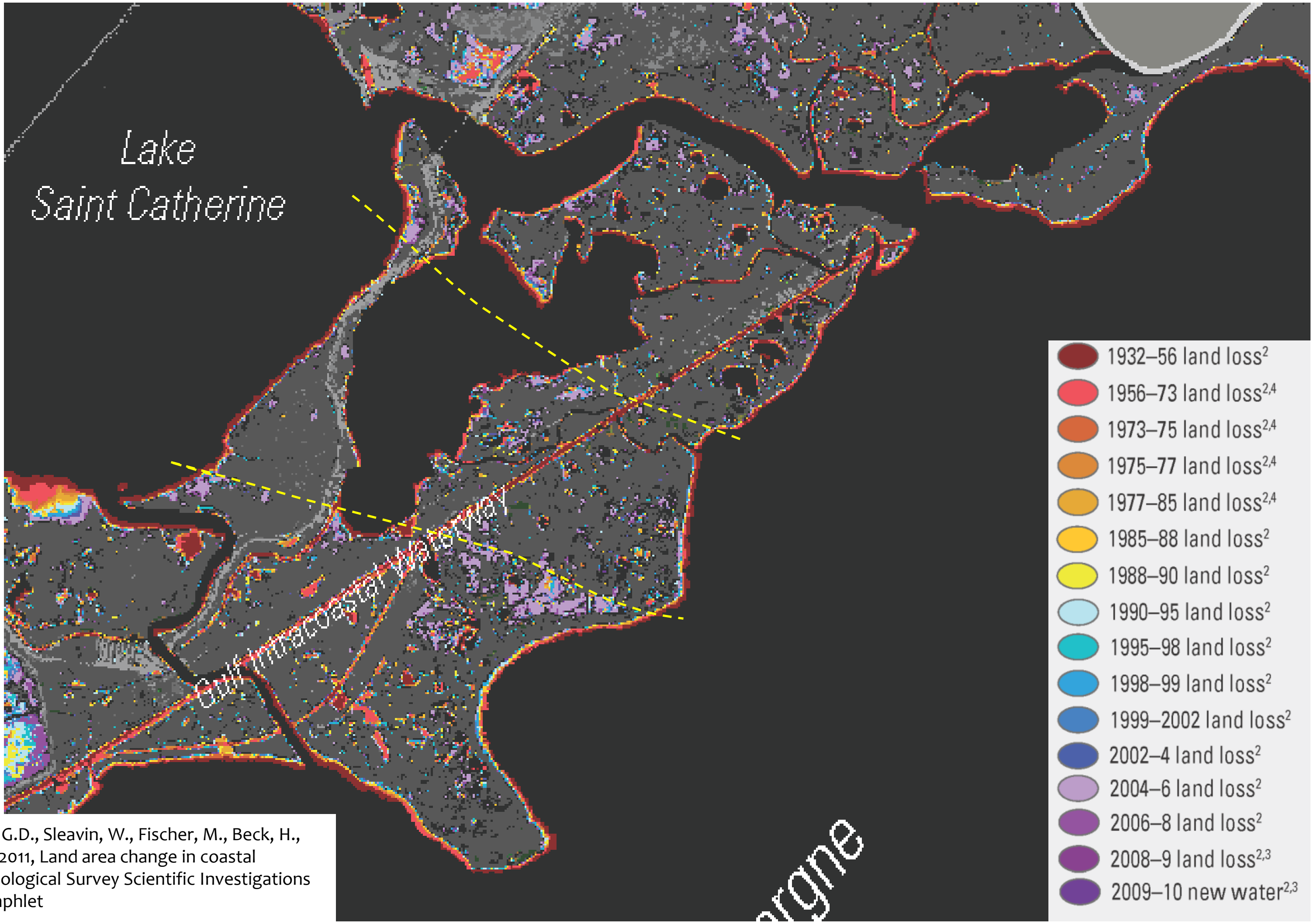
It is suggested here that activity on the fault had the effect of weakening the grasses so that they were susceptible to erosion by the Hurricane.



Mapping Faults

The areas of land loss that occurred in association with Hurricane Katrina are indicated by the purple areas on the USGS Land Area Change Map published in 2011.

If the suggestion that these areas are related to the activity of the faults is correct, these areas are likely to also be areas to watch for future land loss.



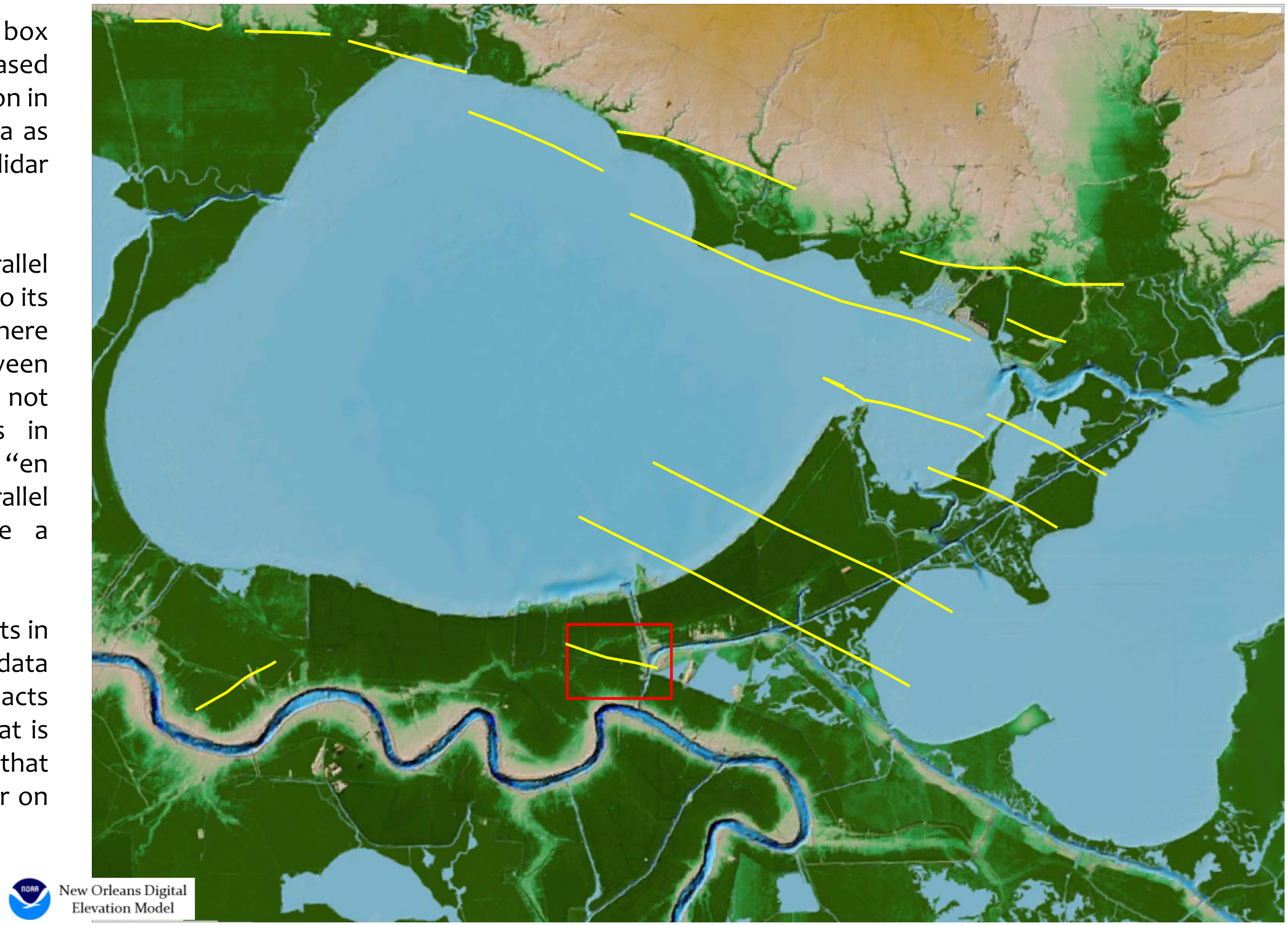
Couvillion, B.R., Barras, J.A., Steyer, G.D., Sleavin, W., Fischer, M., Beck, H., Trahan, N., Griffin, B., Heckman, D., 2011, Land area change in coastal Louisiana from 1932 to 2010: U.S. Geological Survey Scientific Investigations Map 3164, scale 1:265,000, 12 p. pamphlet

Mapping Faults

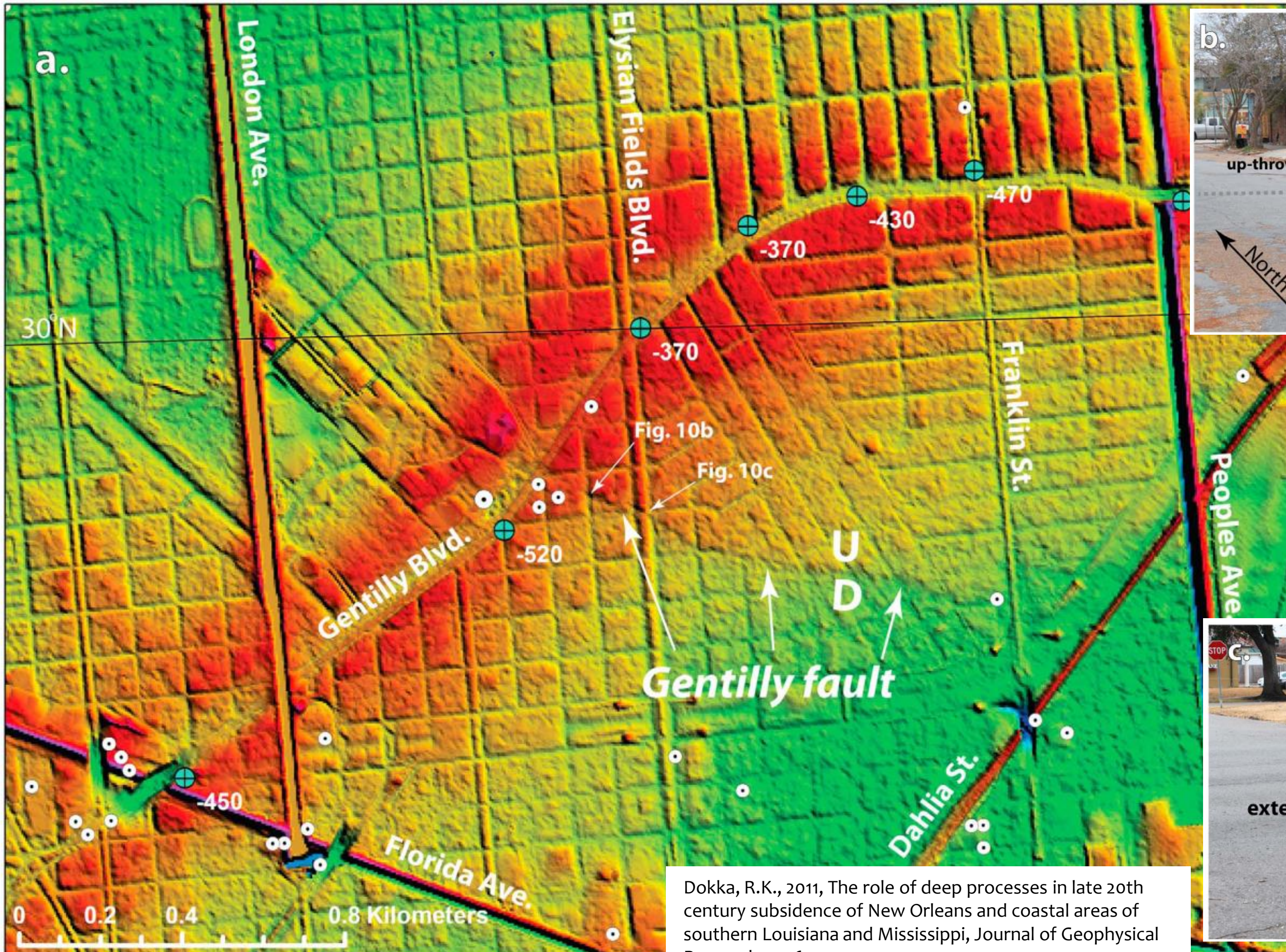
The possible fault in the red box was proposed by Dokka based on subtle changes in elevation in the New Orleans Metro area as seen in high resolution lidar data.

This possible fault is also parallel to the other possible faults to its northeast suggesting that there may be a relationship between all of these faults. It is not uncommon to find faults in nature occurring in these "en echelon" sets that are parallel to each other and share a common genetic origin.

Mapping these an other faults in more detail with seismic data may reveal potential for impacts on surface infrastructure that is equal to or greater than that seen at the Hwy 11 bridge or on the next slide.



Mapping Faults



Dokka, R.K., 2011, The role of deep processes in late 20th century subsidence of New Orleans and coastal areas of southern Louisiana and Mississippi, Journal of Geophysical Research, v. 16, 25 pgs

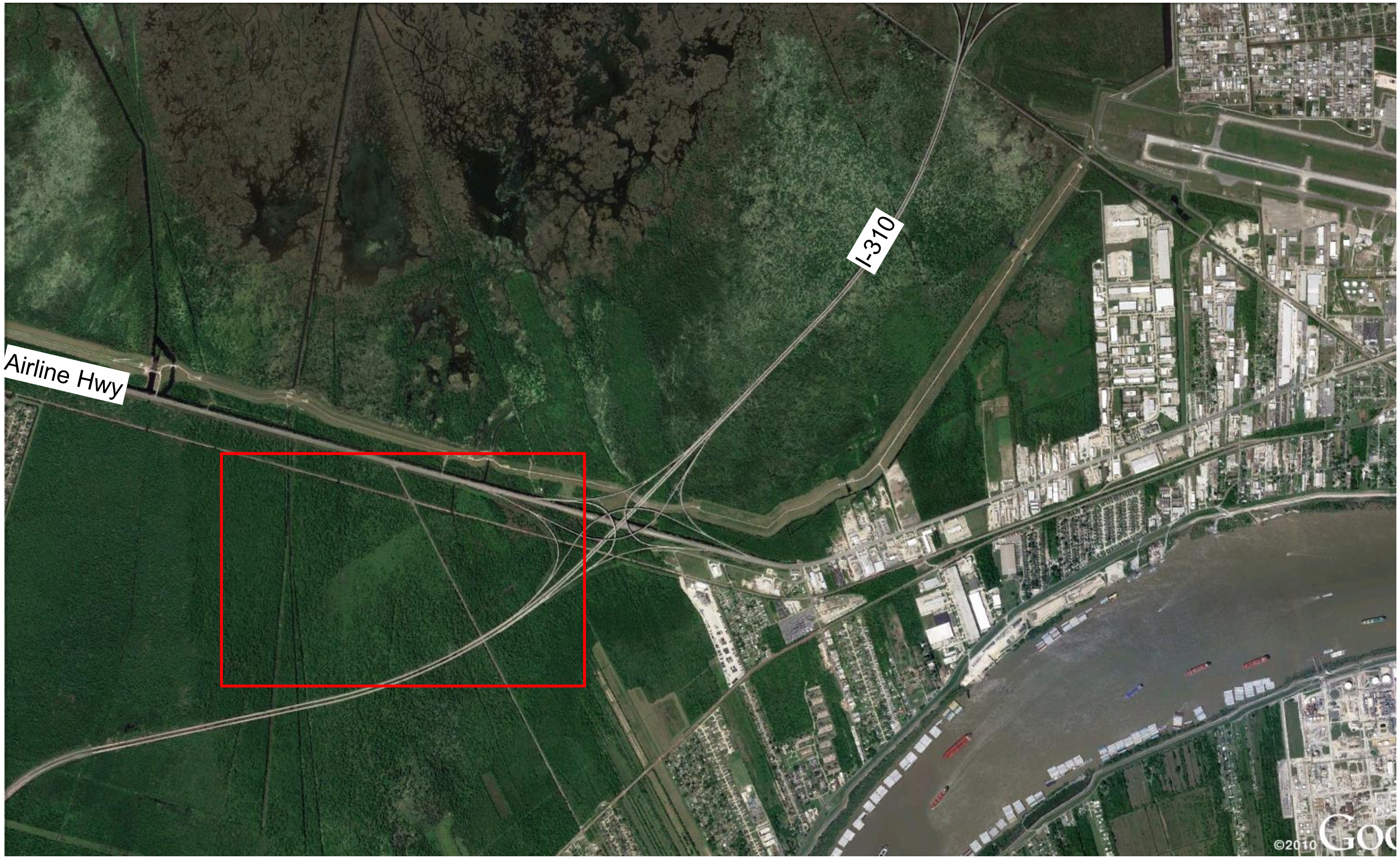
Mapping Faults

The fault trace in the red box was mapped by New Orleans Geological Society member Eric Broadbridge using a 3D seismic survey to which he has proprietary access.

Broadbridge's interpretation is that the fault can be mapped with the seismic data in this location and extending to the surface. The following two slides show the obvious surface expression of the fault that can be seen on Google Earth imagery.

Broadbridge has also provided a block diagram of the fault showing the offset of subsurface sedimentary layers and the apparent impact of fault activity on the surface flora. This is an obvious area for more detailed research.

Mapping Faults



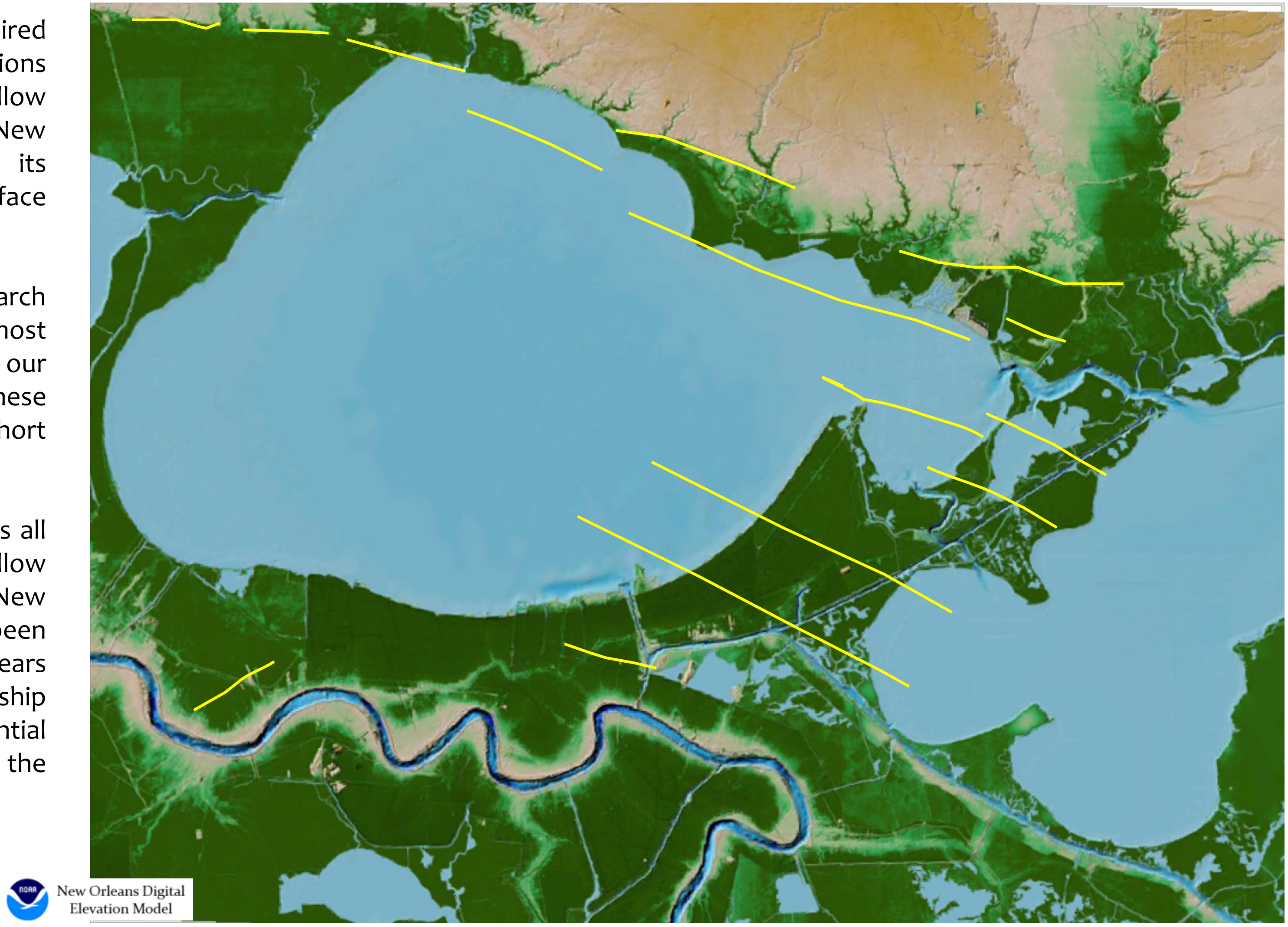
Mapping Faults

Mapping Faults

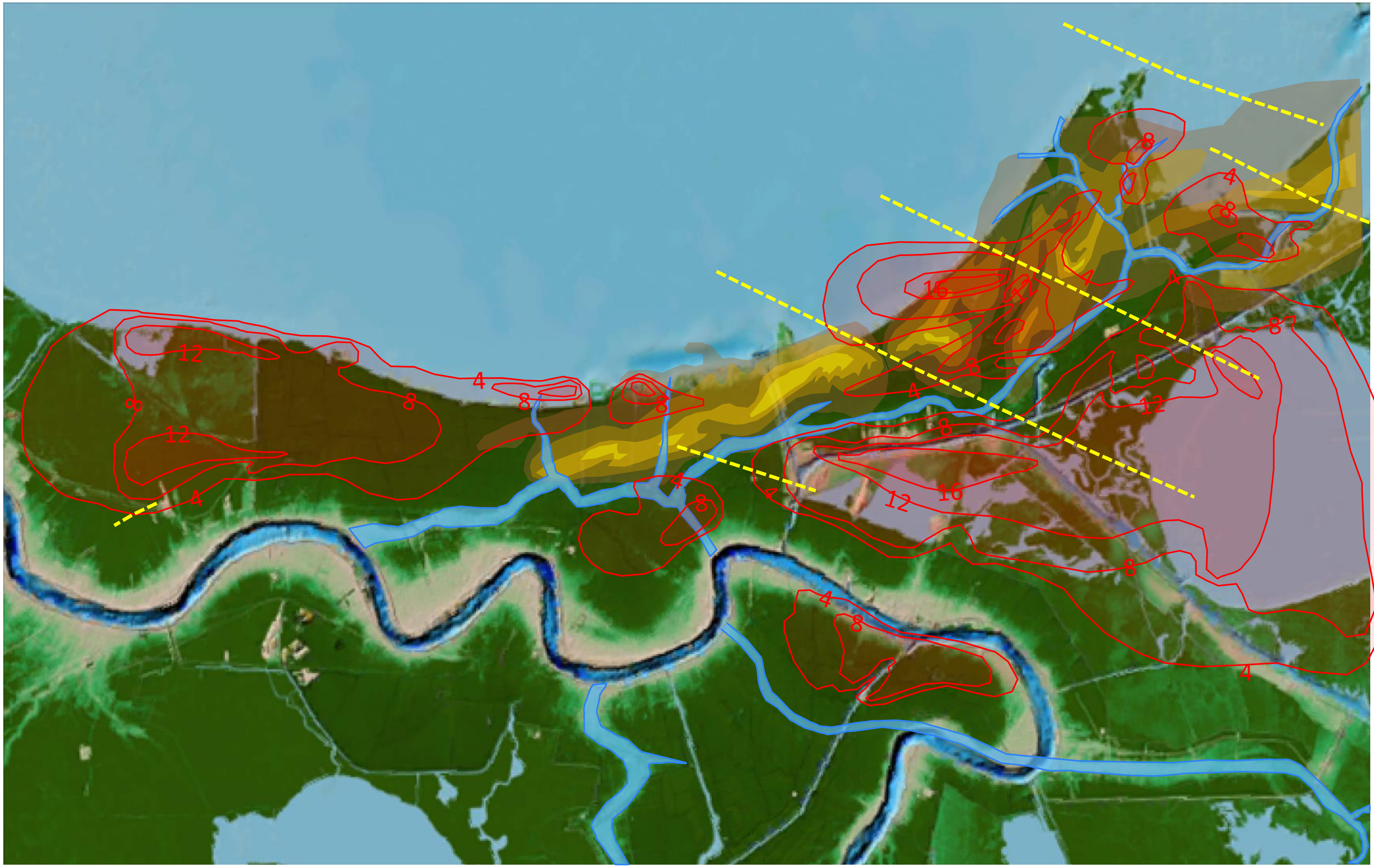
Much more research is required to fully assess the implications for fault activity on the shallow subsurface geology of the New Orleans area, and on its implications for surface infrastructure.

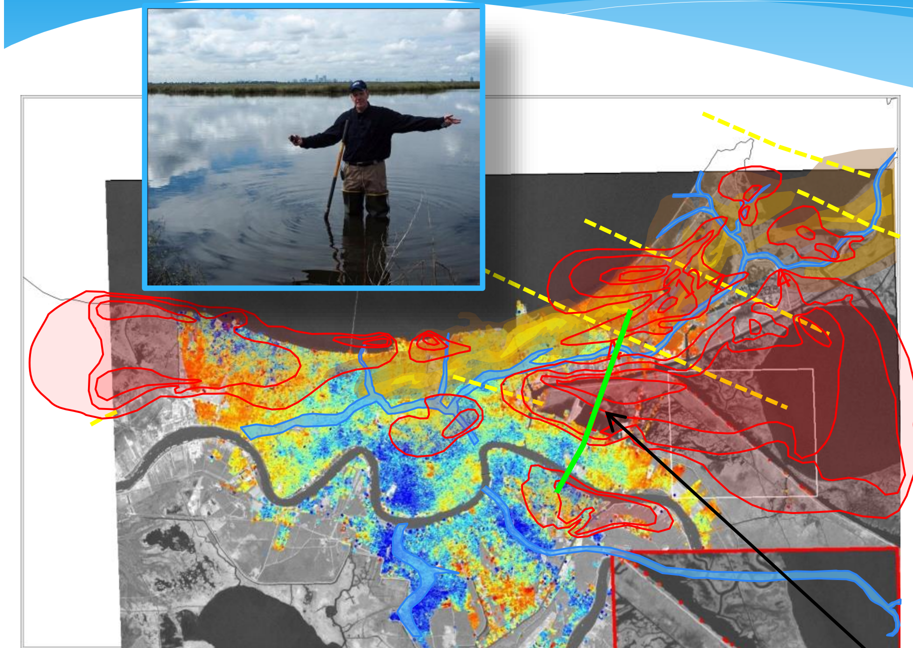
Support of university research efforts is by far the most effective means to enhance our understanding of these potential impacts in the short term.

The following map combines all of the elements of the shallow subsurface geology of the New Orleans area that have been discussed here. There appears to be a strong interrelationship between all of these essential elements – including the possible faults.

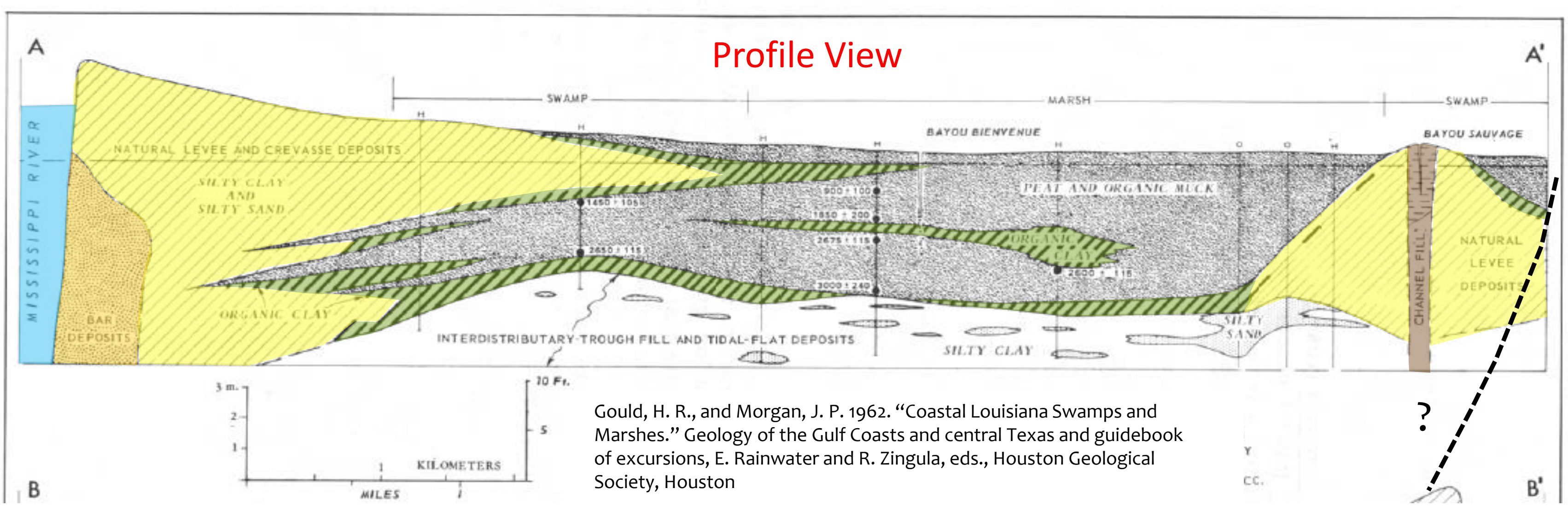


Tying It All Together





The map on the previous slide shows that the areas of thick peat accumulation that are associated with areas of higher subsidence also appear to be segmented by faults proposed by Dokka. The profile below across the Central Wetlands Unit shows that it is underlain by the thickest accumulation of peat in the area. It also has the highest current rates of subsidence, as evidence by the elevation of Old Paris Road shown in the picture of John Snell standing on the road bed. It may be possible that these faults are important in controlling the thickness of the compactable sediments in the subsurface, and thereby play dual role in impacting subsidence.

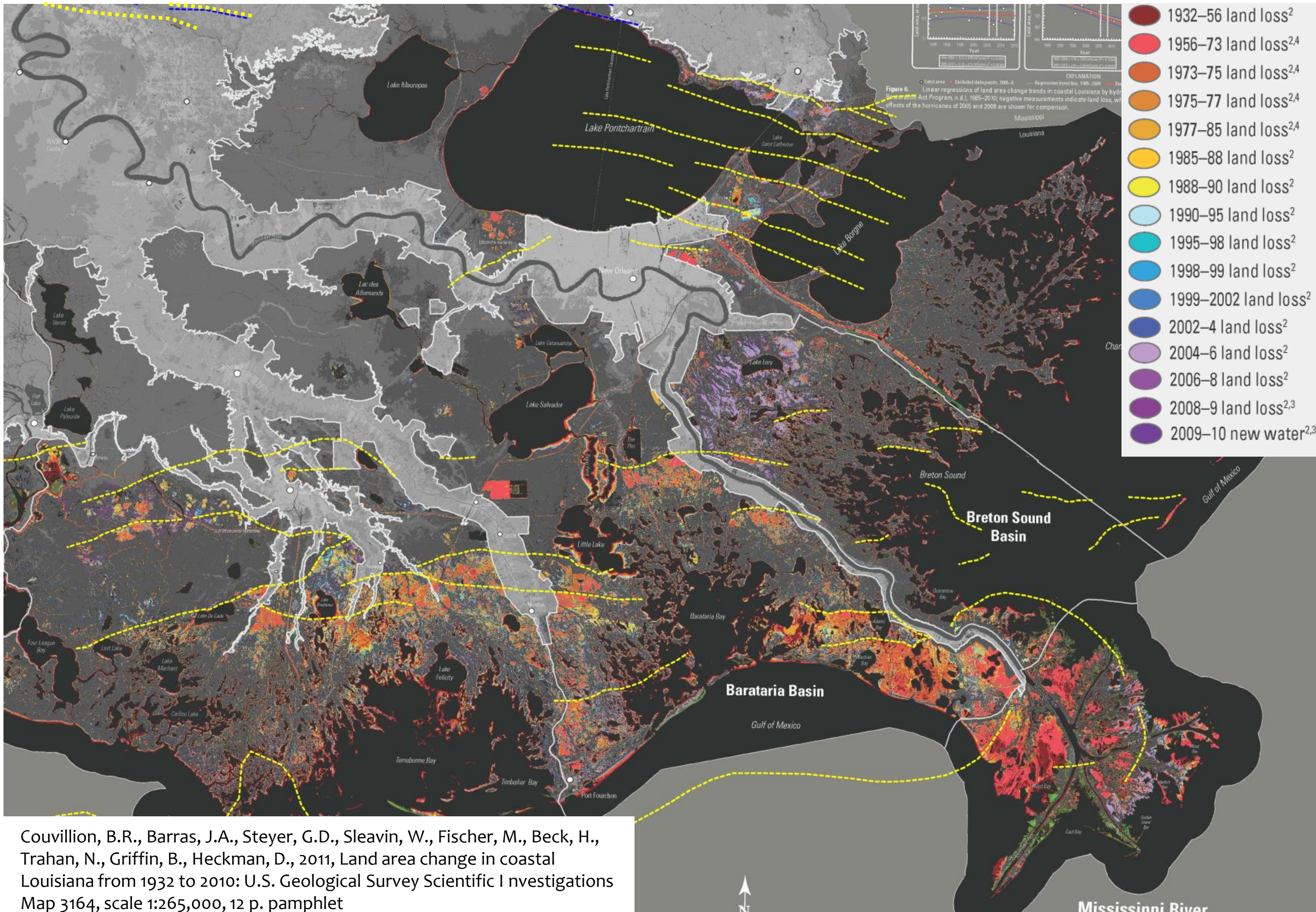


Gould, H. R., and Morgan, J. P. 1962. “Coastal Louisiana Swamps and Marshes.” Geology of the Gulf Coasts and central Texas and guidebook of excursions, E. Rainwater and R. Zingula, eds., Houston Geological Society, Houston

NOGS Research Effort

The New Orleans Geological Society Proposal Document for the research initiative includes this map of a first order approximation of the surface fault traces across Southeast Louisiana.

It is a contention of the research initiative that mapping of these possible faults in detail with 3-D seismic data will provide significant insight into the potential impacts of faults on the land surface – including impacts on infrastructure and causes of coastal land loss.



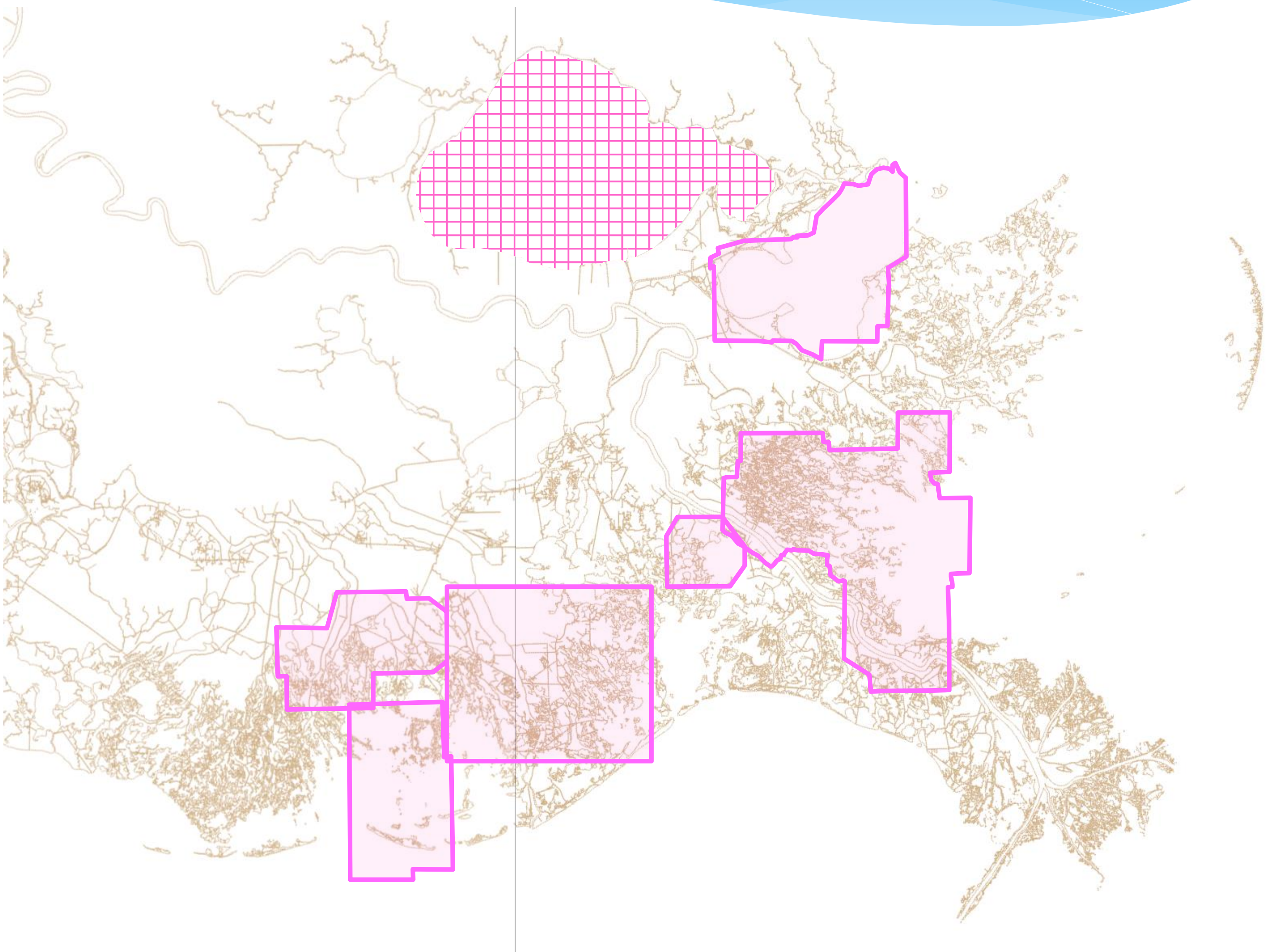
Couvillion, B.R., Barras, J.A., Steyer, G.D., Sleavin, W., Fischer, M., Beck, H., Trahan, N., Griffin, B., Heckman, D., 2011, Land area change in coastal Louisiana from 1932 to 2010: U.S. Geological Survey Scientific I nvestigations Map 3164, scale 1:265,000, 12 p. pamphlet

NOGS Research Effort

To date NOGS has contributed significantly to the volume of 3-D seismic data that has been made available for research at area universties.

This map of oil and gas industry seismic data made available for research in the coastal zone includes the Lake Pontchartrain 2-D grid and the other 3-D surveys.

It can be reasonably estimated that the total original acquisition cost of these seismic surveys was about $200 million. NOGS is working to expand this coverage.



Thank-you