

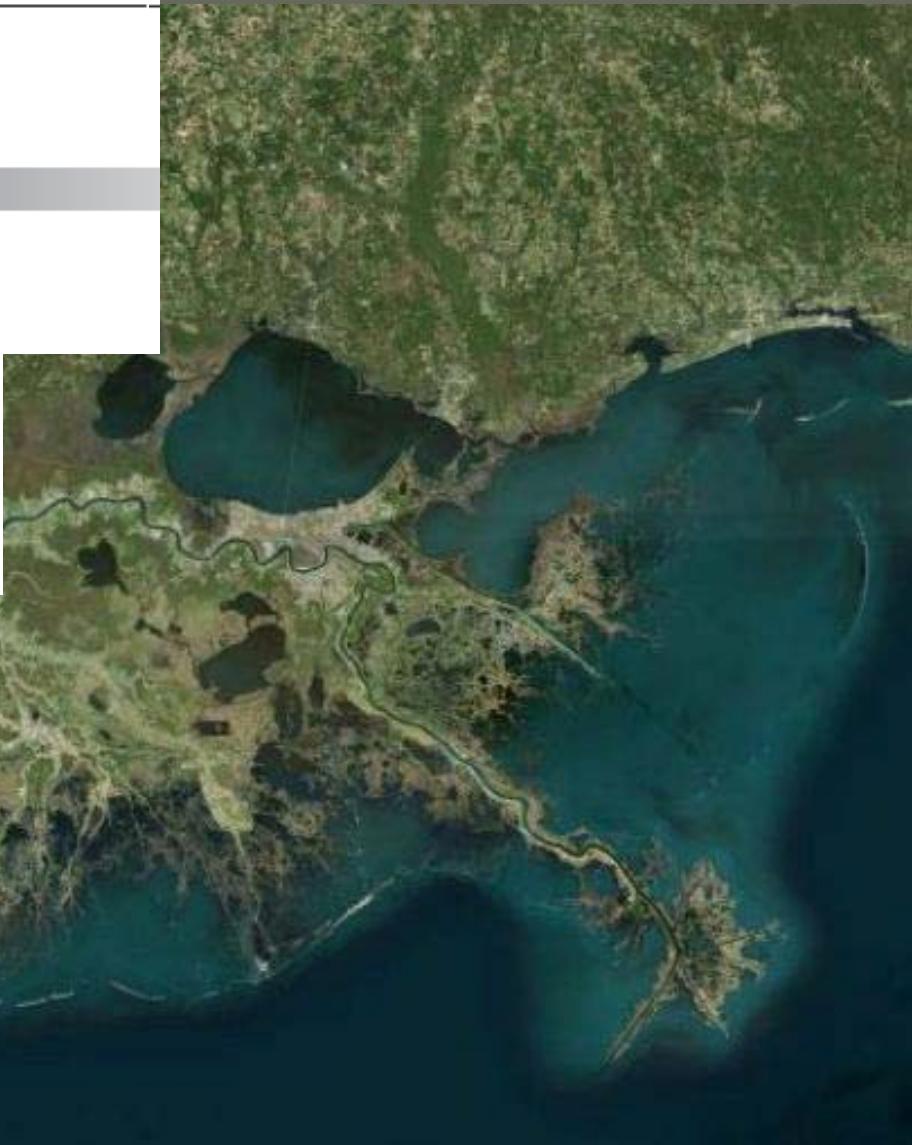
Geology of the coastal wetlands of south Louisiana

A presentation to:
The Association of Levee Boards of Louisiana
May 7, 2015

FORUM

Earth Scientists and Public Policy: Have We Failed New Orleans?

—TIMOTHY H. DIXON, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Fla.; E-mail: tdixon@rsmas.miami.edu; and ROY K. DOKKA, Louisiana State University, Baton Rouge.



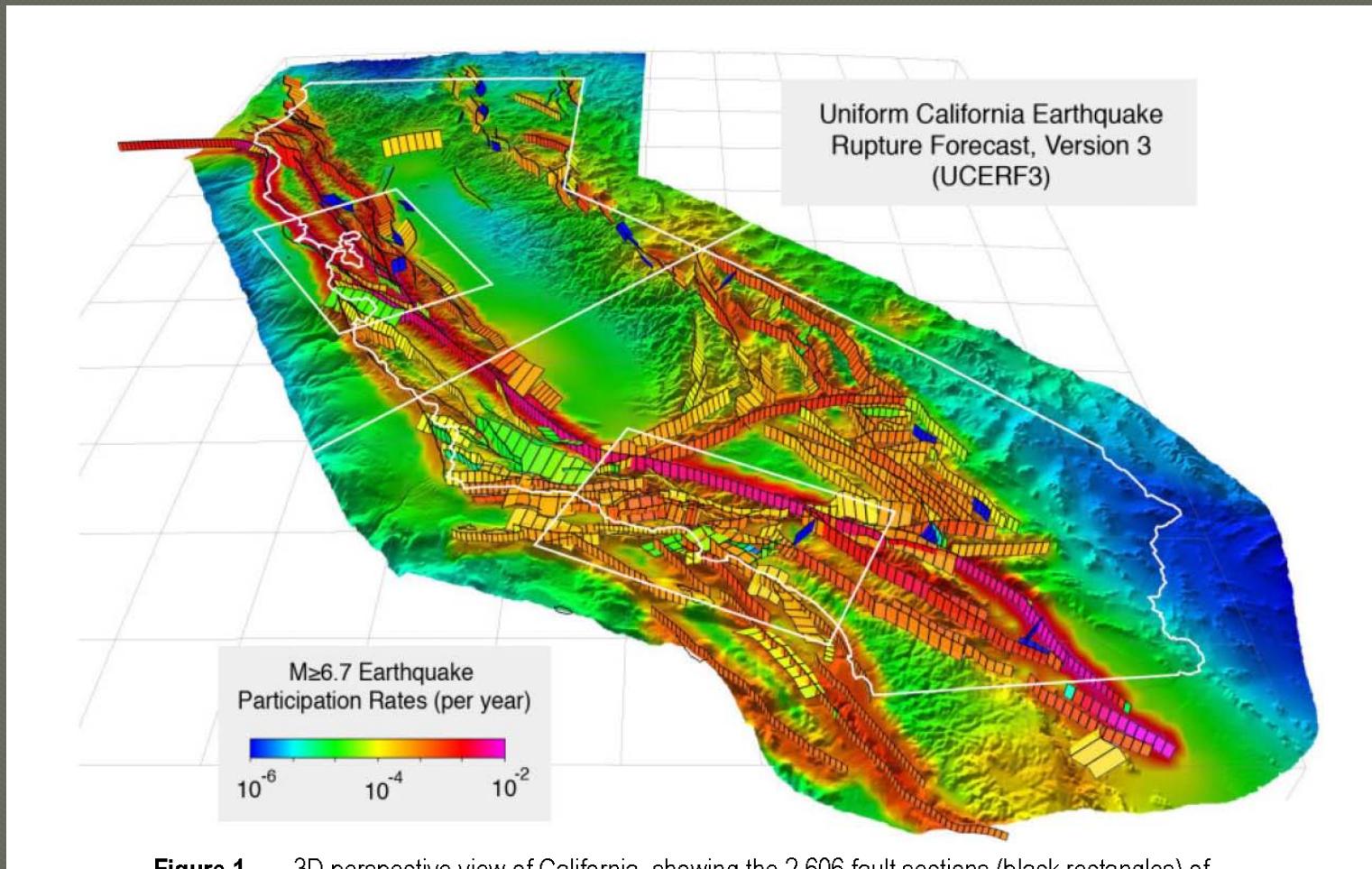
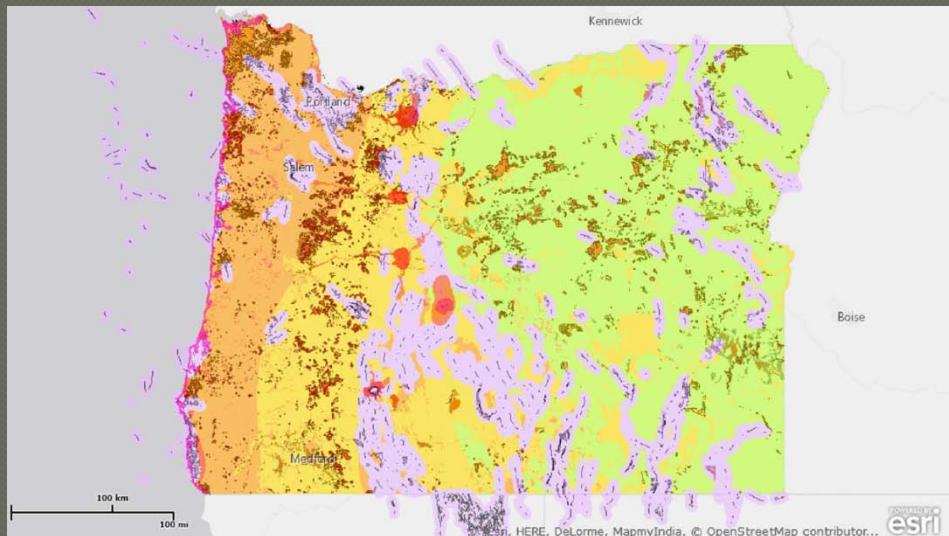


Figure 1. 3D perspective view of California, showing the 2,606 fault sections (black rectangles) of UCERF Fault Model 3.1 (FM 3.1). Colors indicate the long-term rate at which each area participates in $M \geq 6.7$ earthquakes, averaged over all 720 UCERF3 logic tree branches for FM 3.1, and including aftershocks. The entire colored area represents the UCERF model region, which comprises California and a buffer zone. The white boxes define the San Francisco Bay area and Los Angeles regions used in various calculations, and the white line crossing the state is our definition of northern versus southern California. The Cascadia megathrust is not shown on this map; it and the Mendocino transform fault (which is shown) extend beyond the UCERF model region.

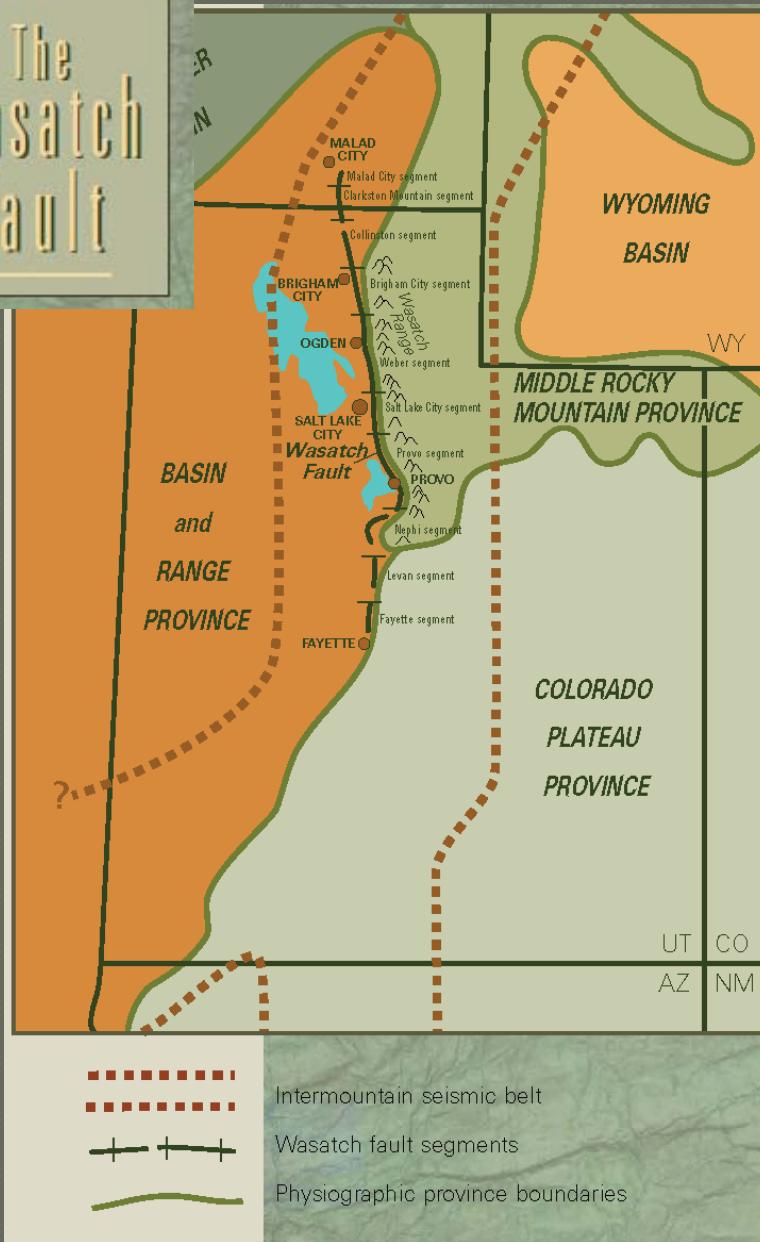


Oregon HazVu: Statewide Geohazards Viewer

Oregon Department of Geology and Mineral Industries

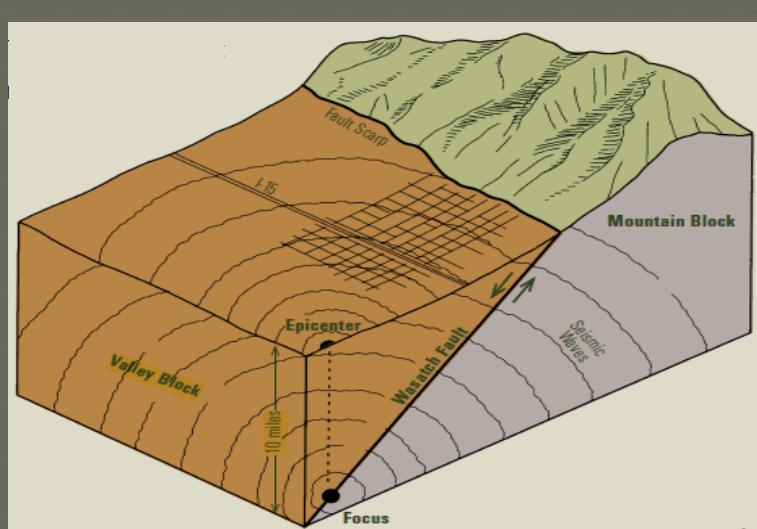
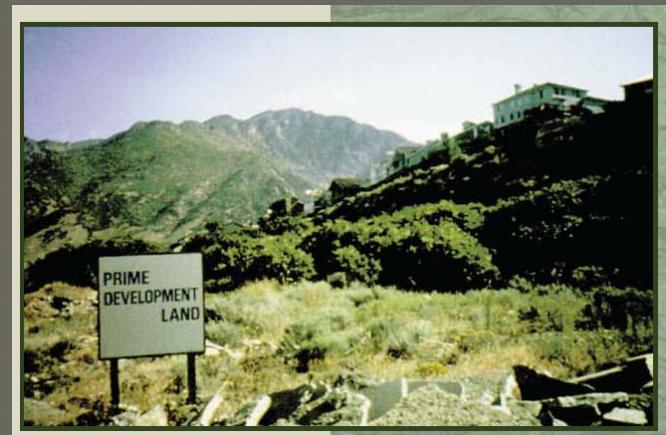
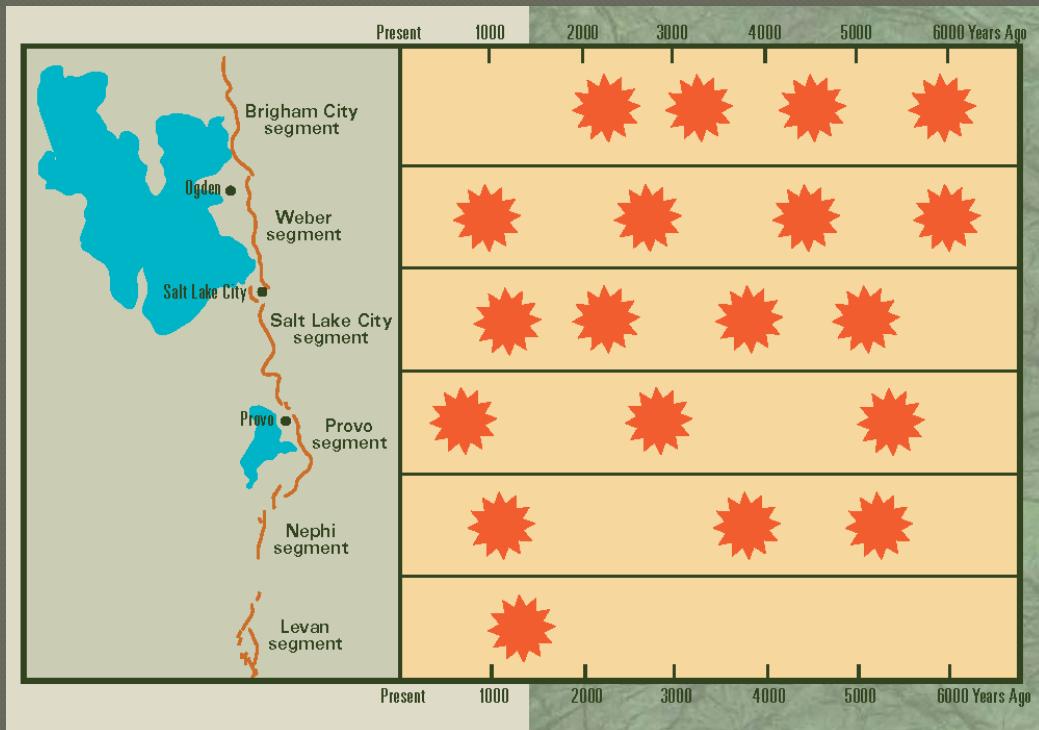


The Wasatch Fault



Utah Geological Survey
Public Information Series 40
1996

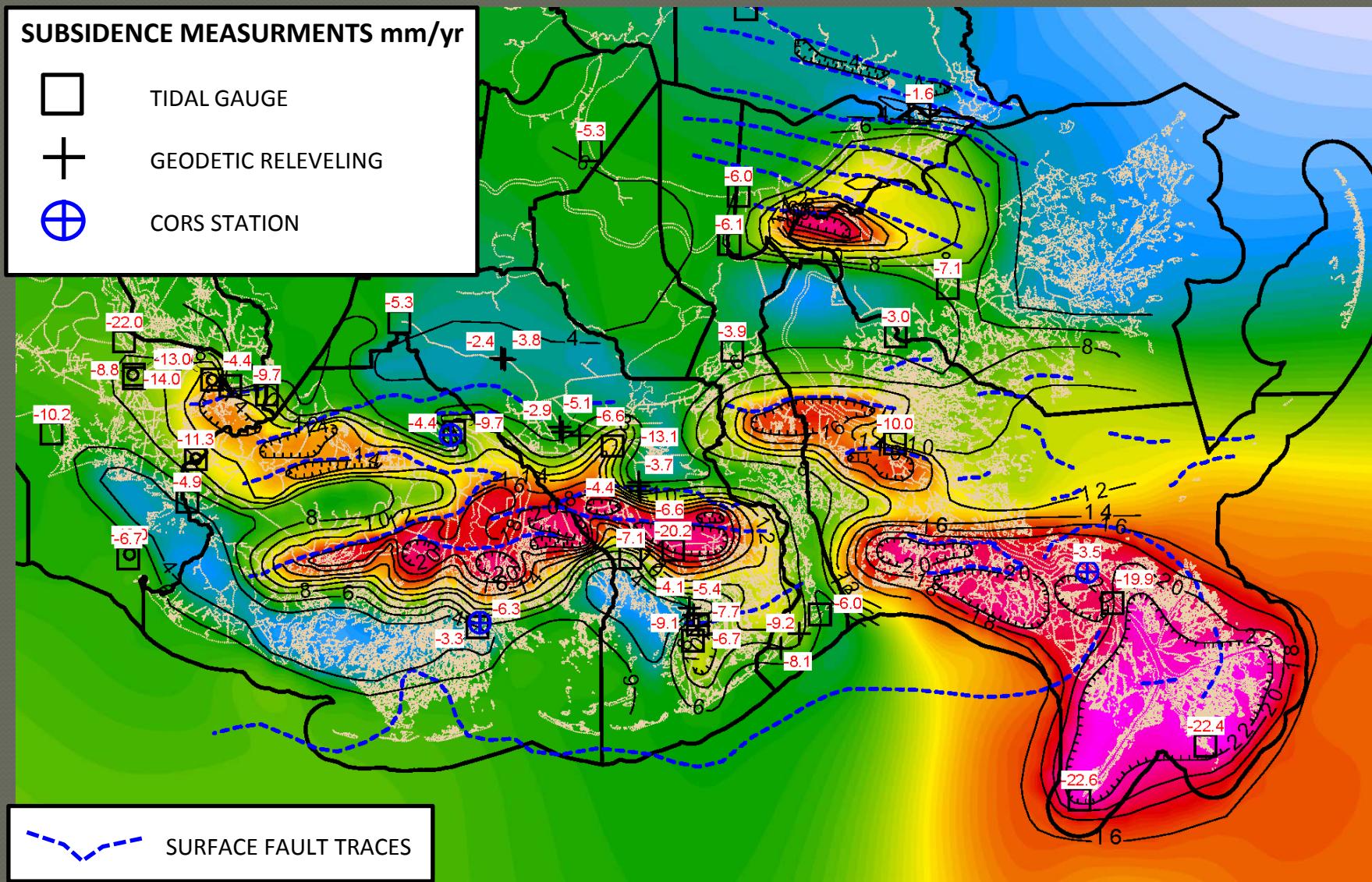


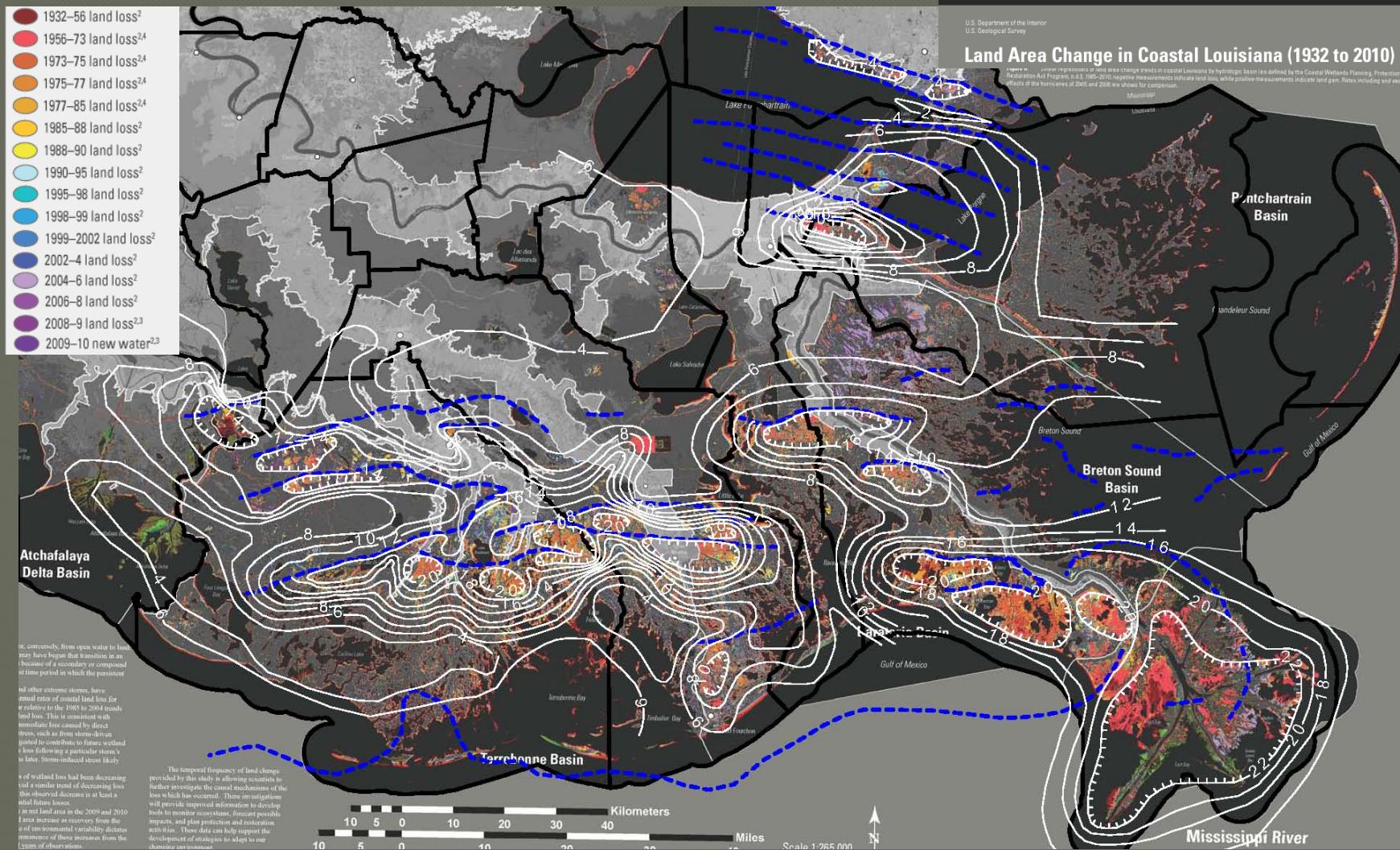


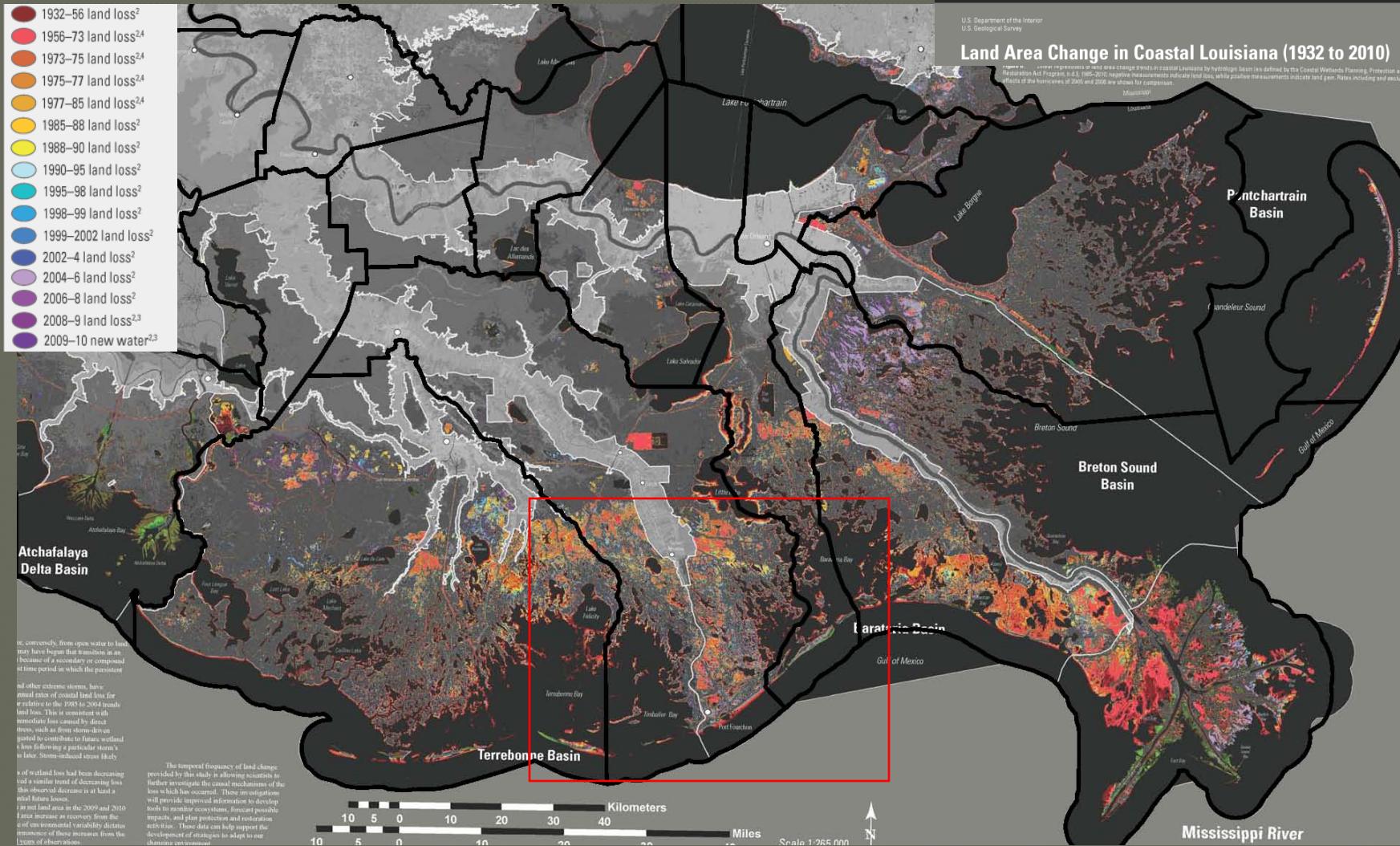
Louisiana Geohazard Map ?

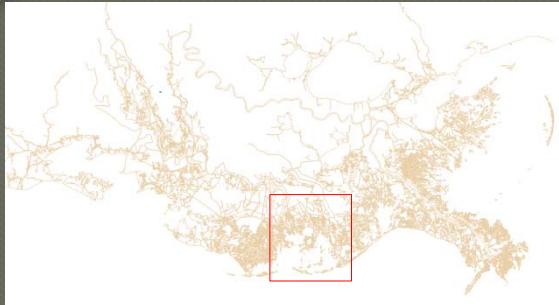


Louisiana Geohazard Map – a proposal



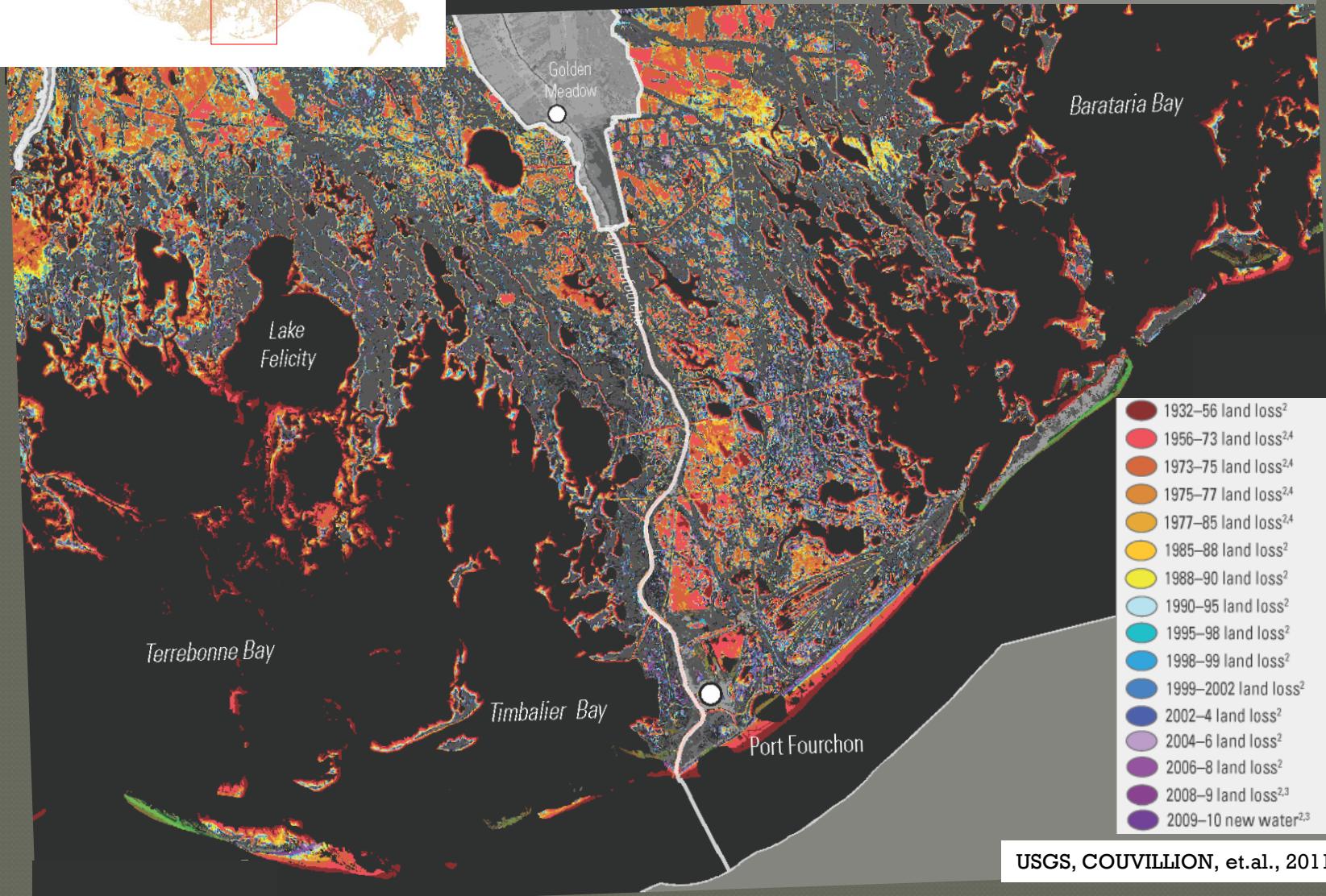




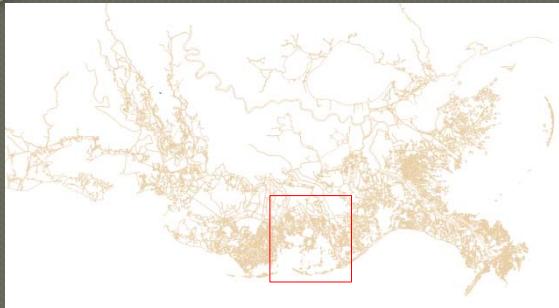


U.S. Department of the Interior
U.S. Geological Survey

Land Area Change in Coastal Louisiana (1932 to 2010)



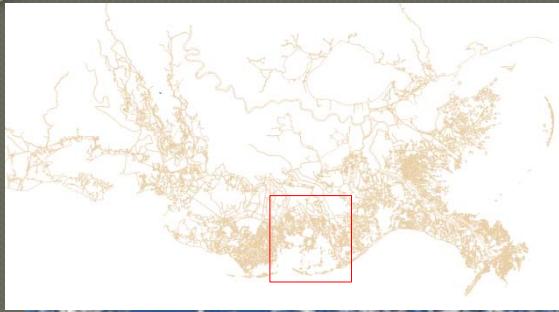
USGS, COUVILLION, et.al., 2011



Land Area Change – over 78 years

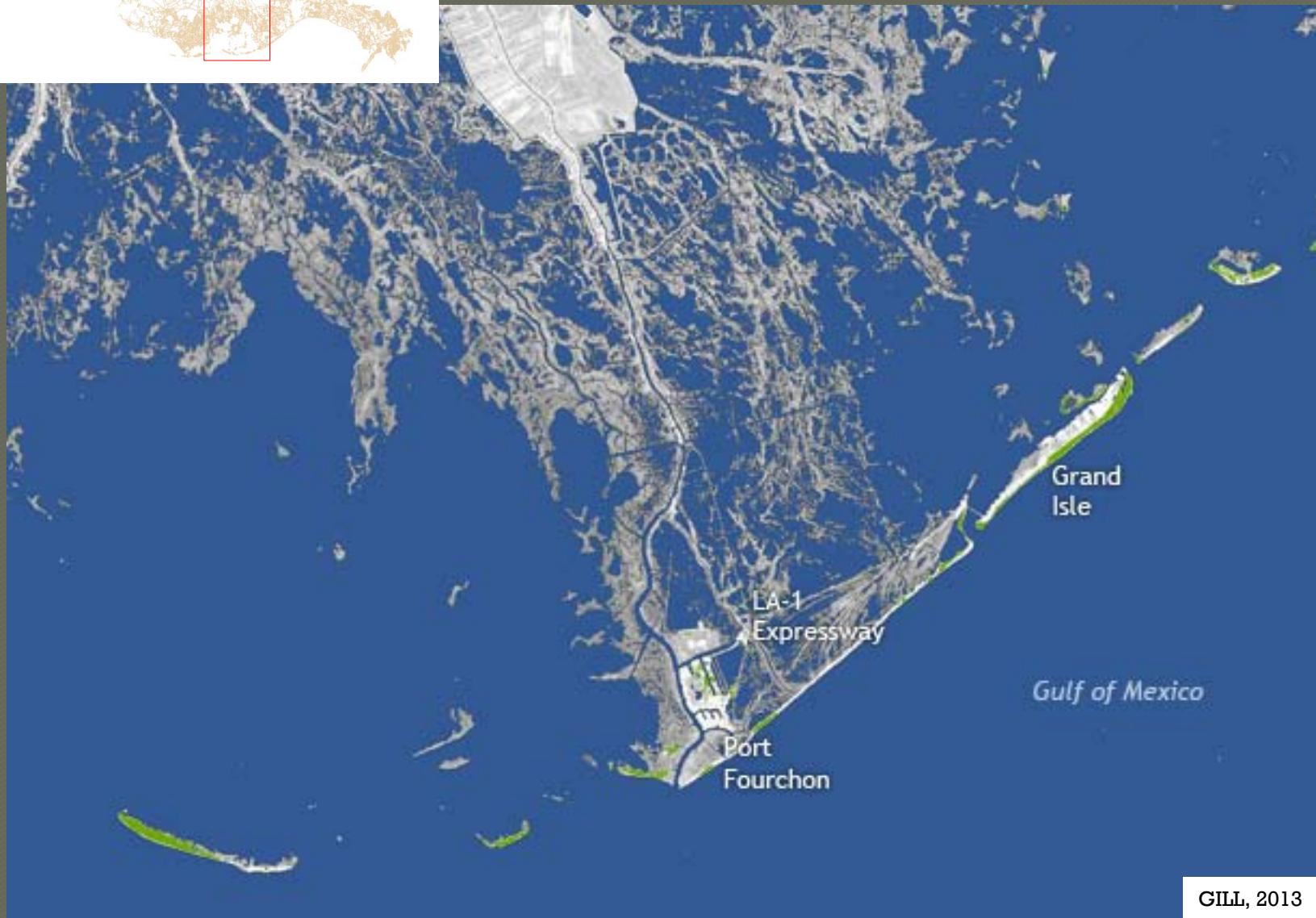
1932

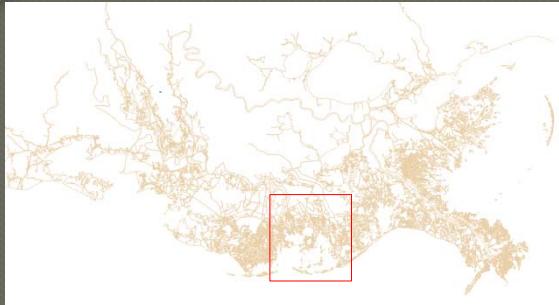




Land Area Change – over 78 years

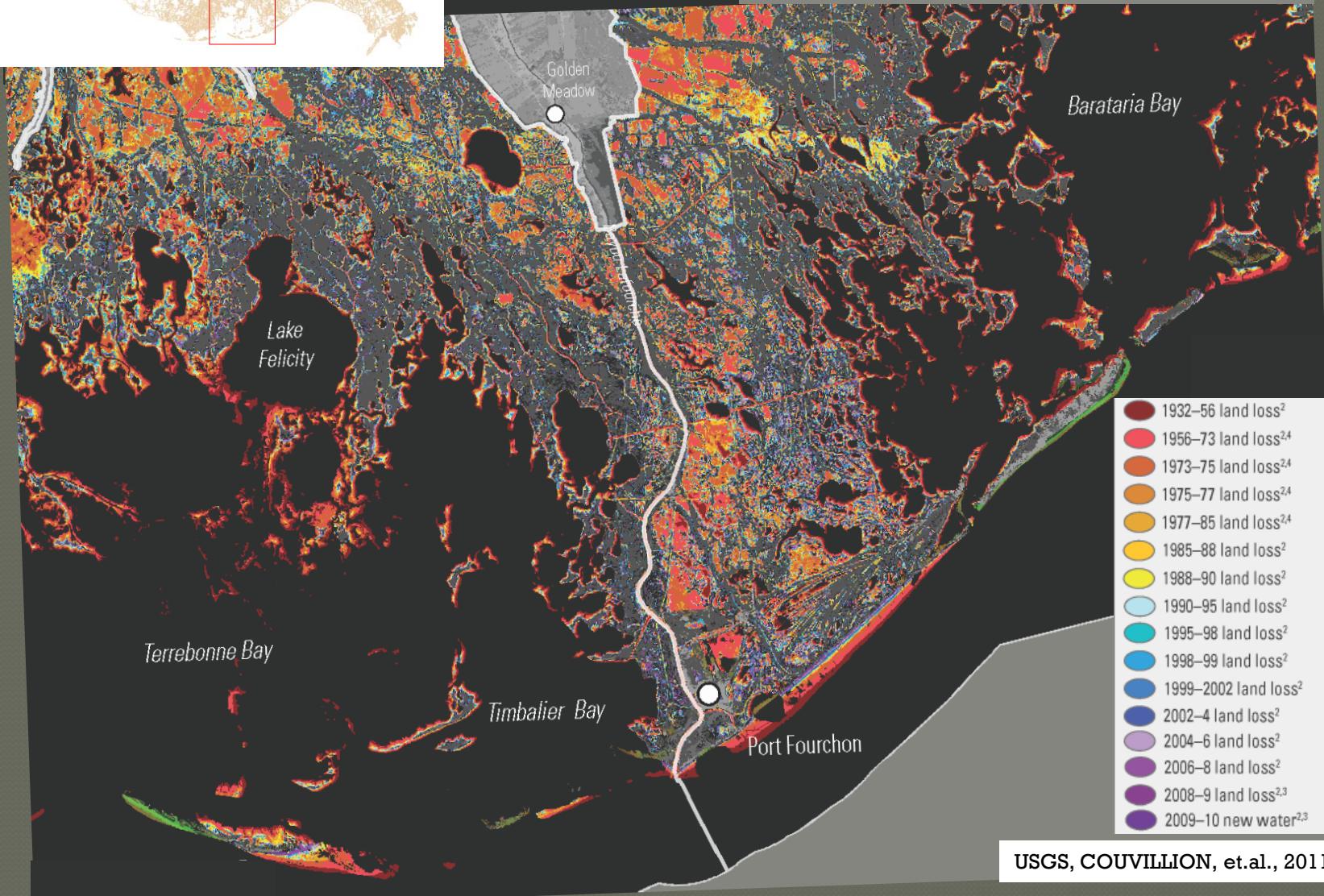
2010



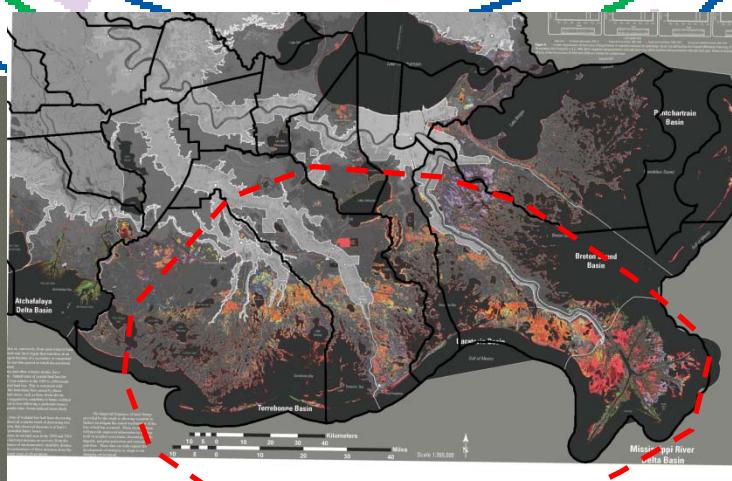
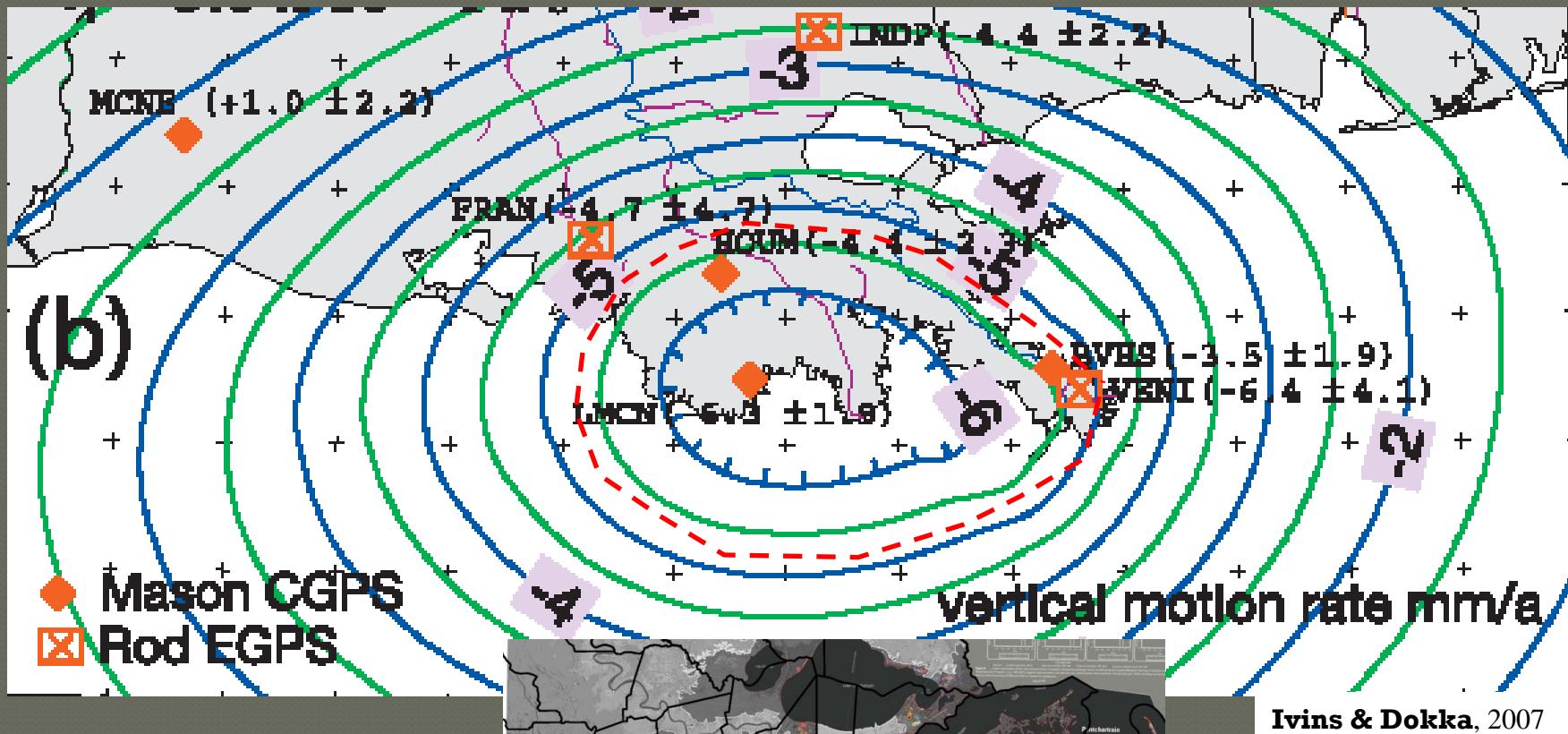


U.S. Department of the Interior
U.S. Geological Survey

Land Area Change in Coastal Louisiana (1932 to 2010)



Subsidence and Land Loss

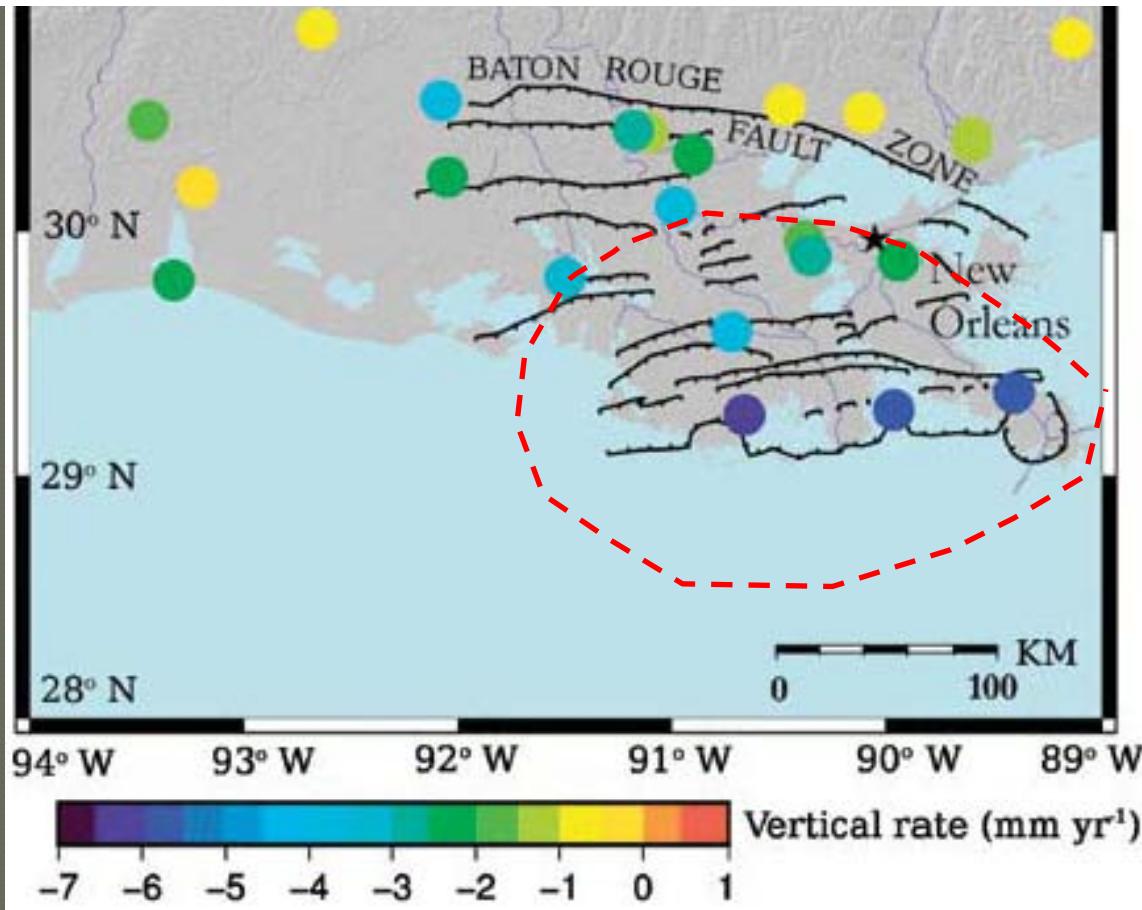


Hot off the Press

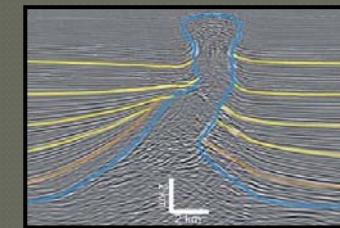
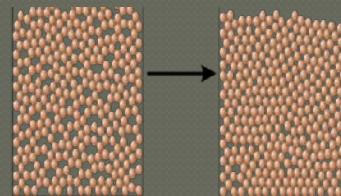
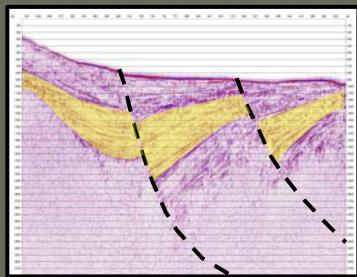
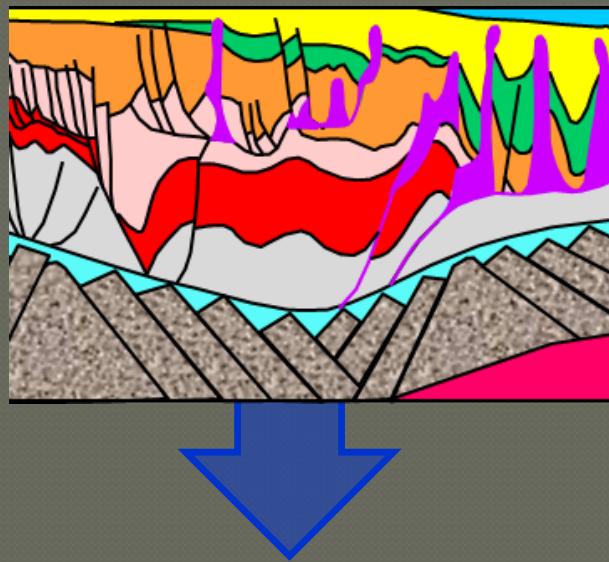
Geology, published online on 27 April 2015 as doi:10.1130/G36598.1

A three-dimensional surface velocity field for the Mississippi Delta:
Implications for coastal restoration and flood potential

Makan A. Karegar, Timothy H. Dixon, and Rocco Malservisi



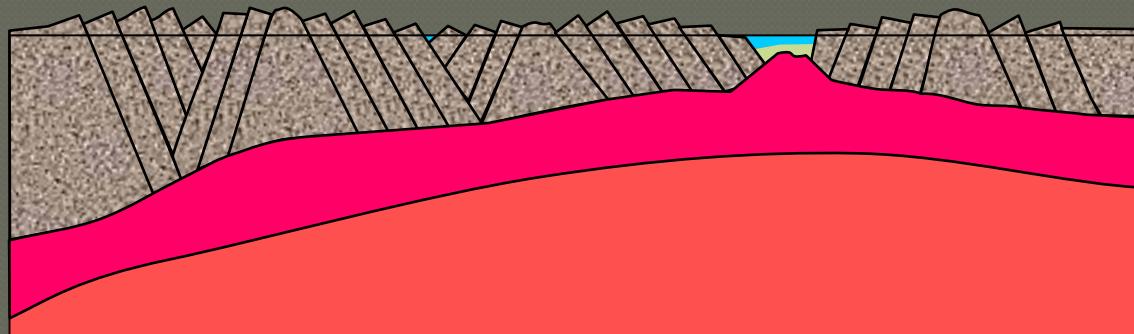
Mechanisms of Subsidence



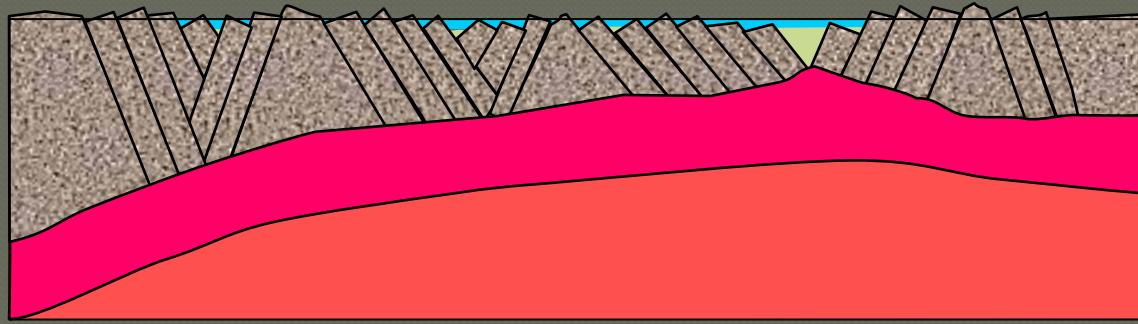
Tectonic Subsidence



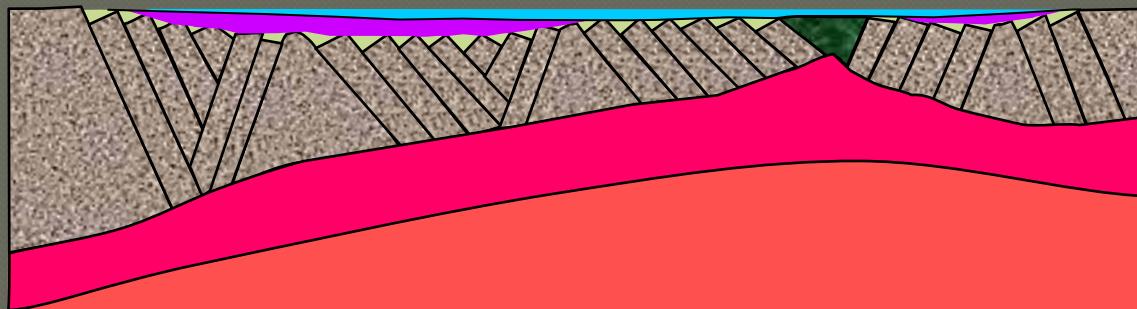
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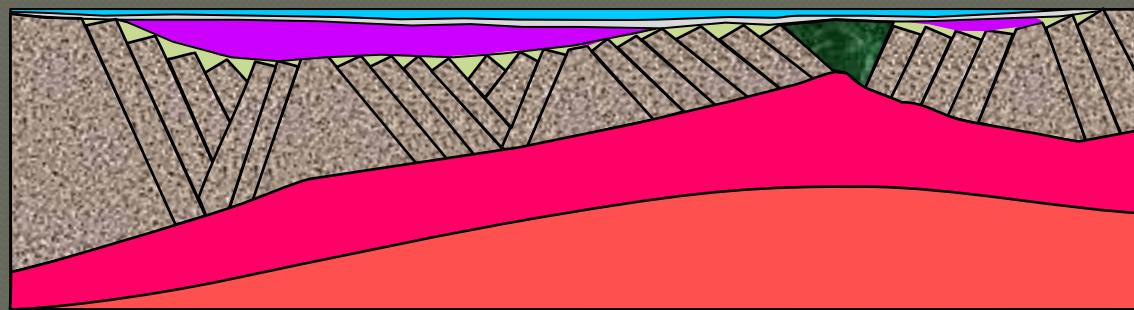
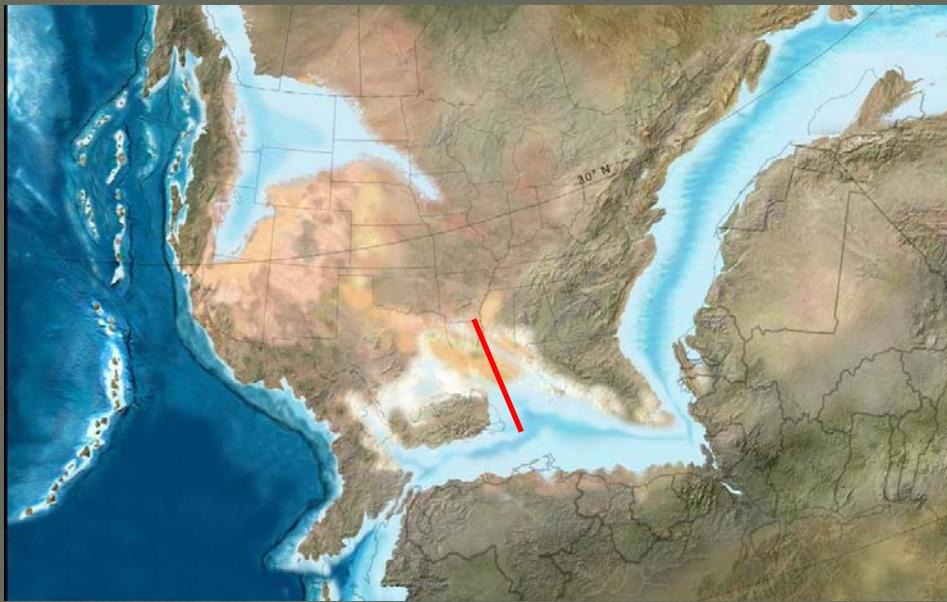
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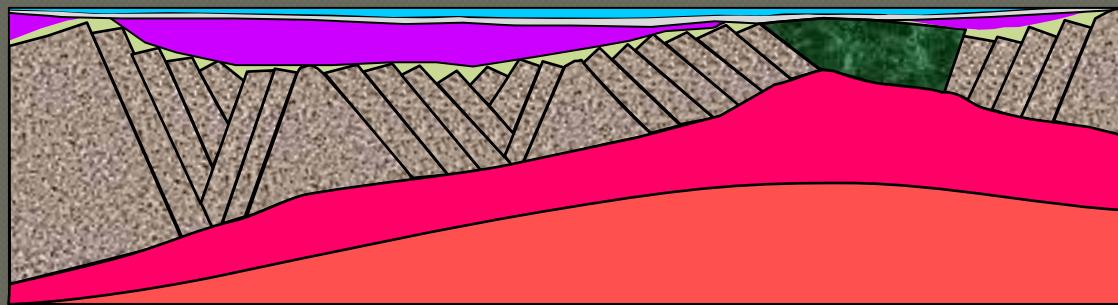
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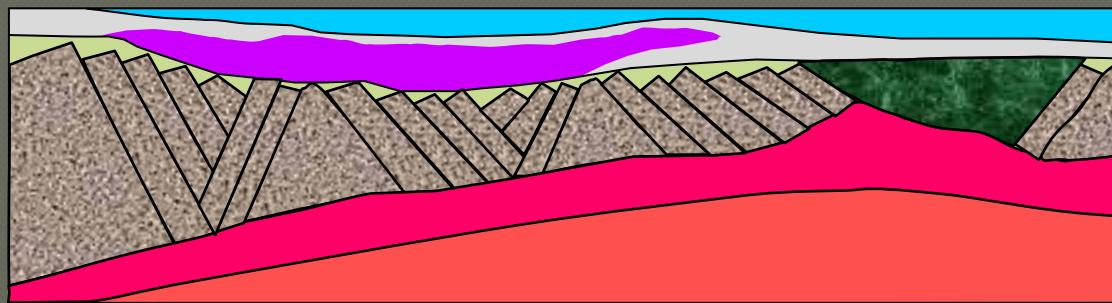
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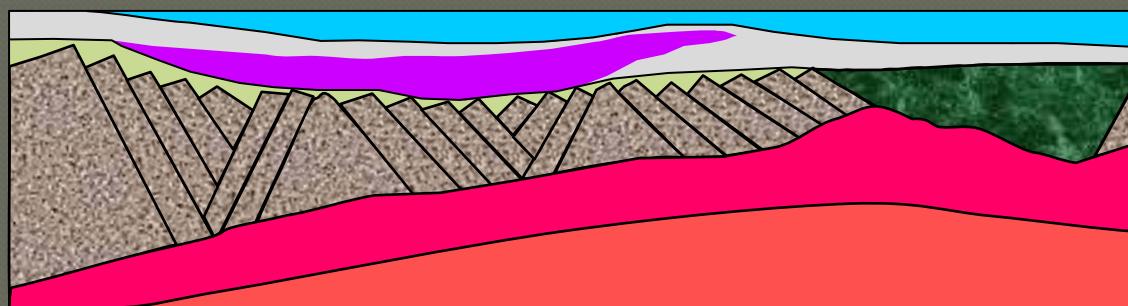
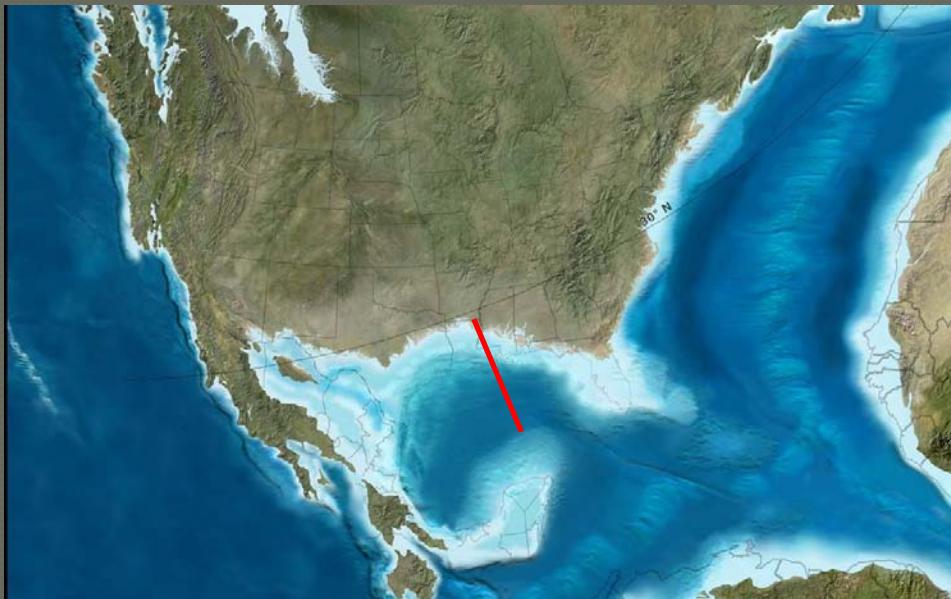
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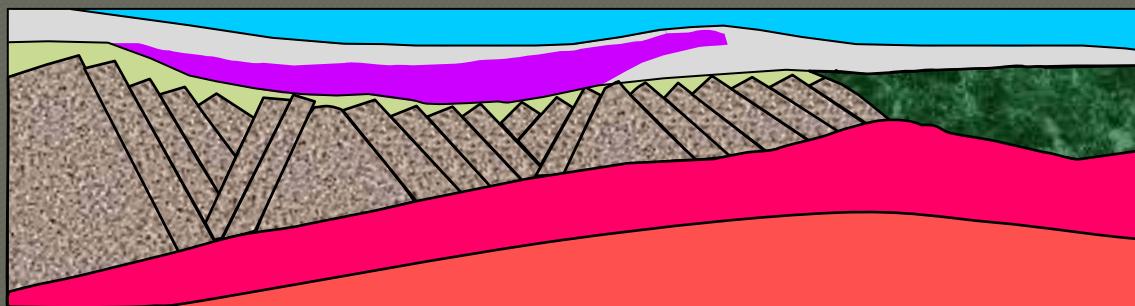
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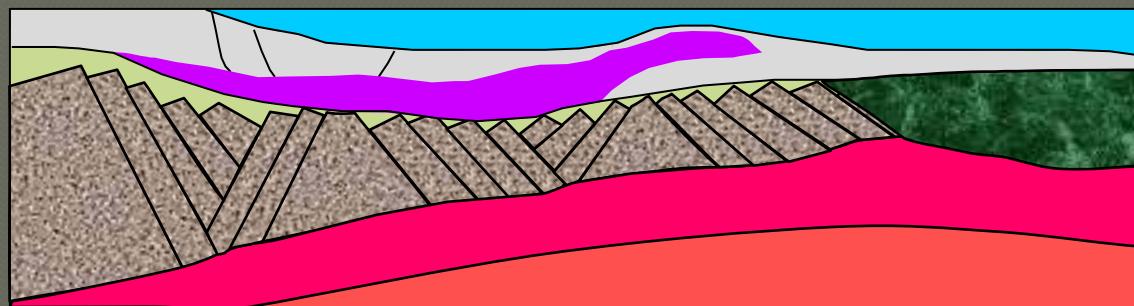
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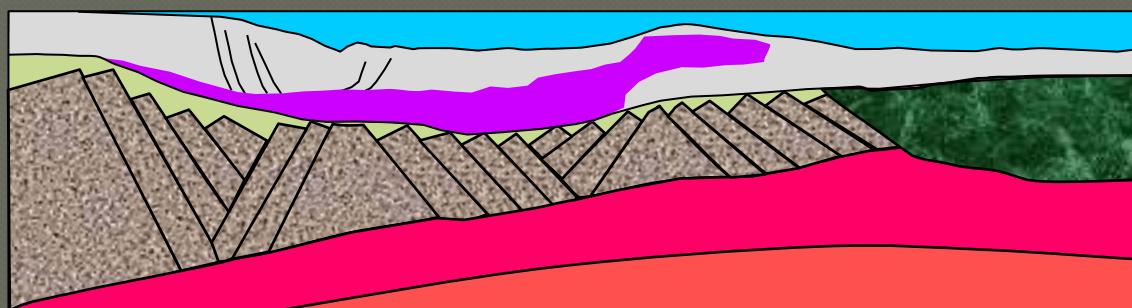
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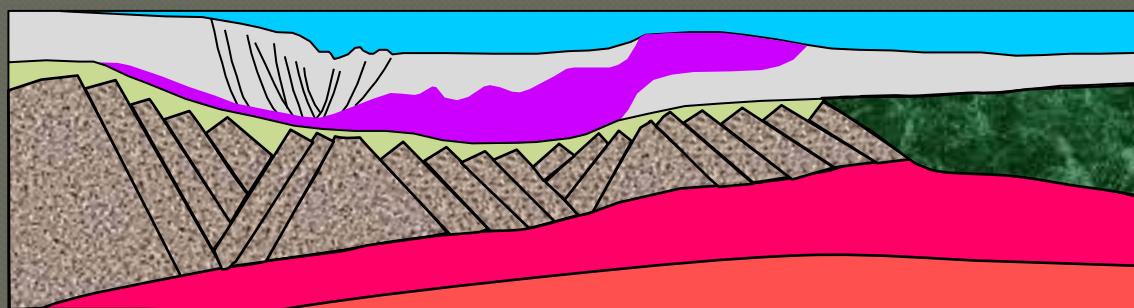
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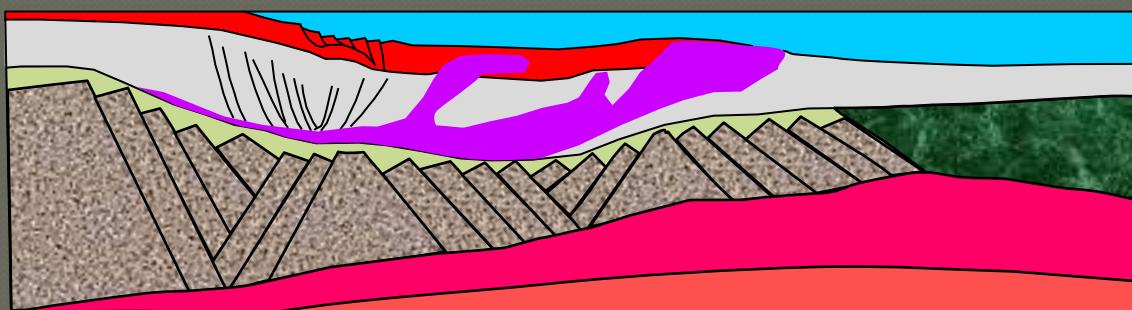
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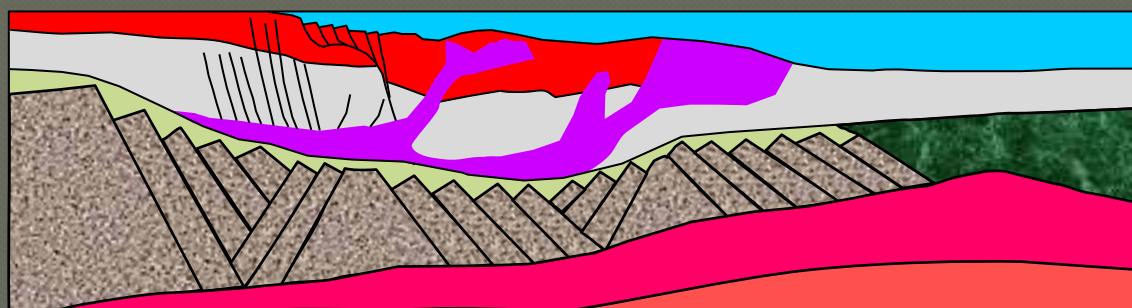
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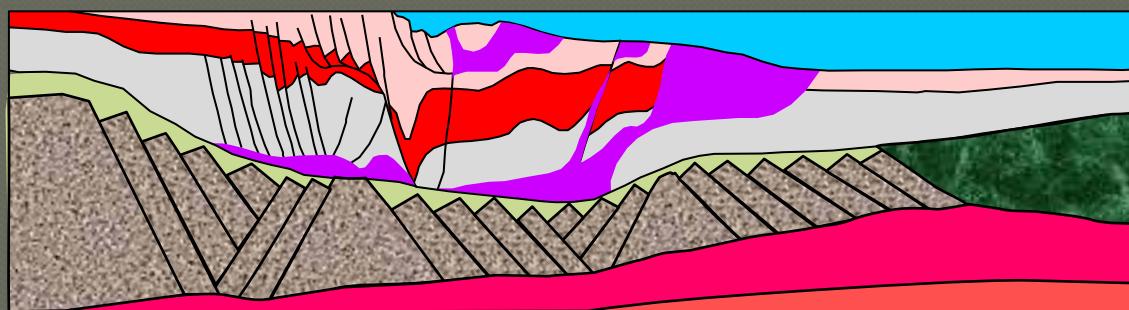
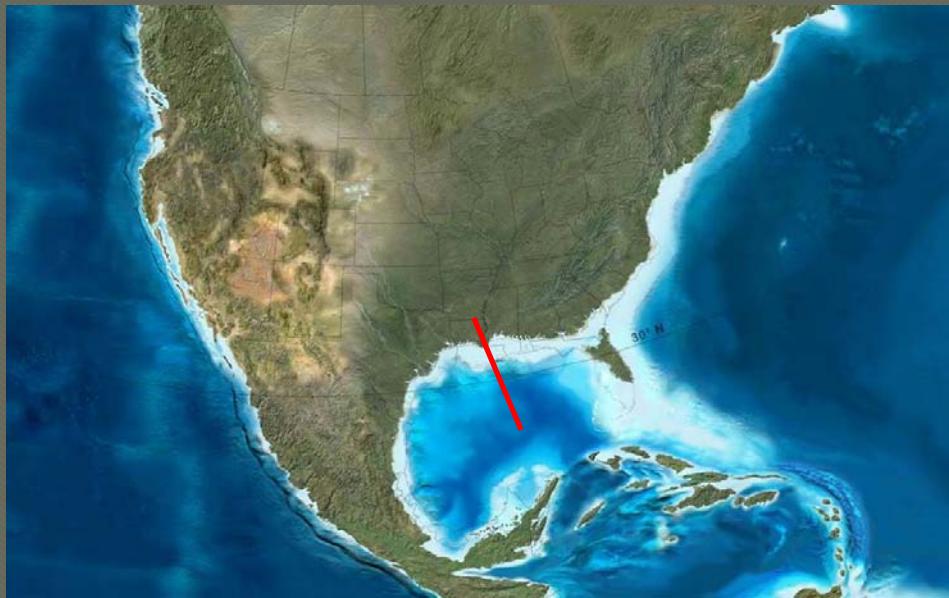
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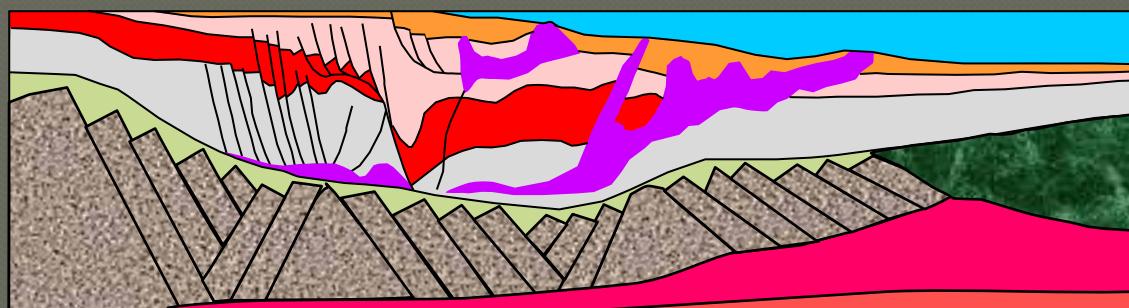
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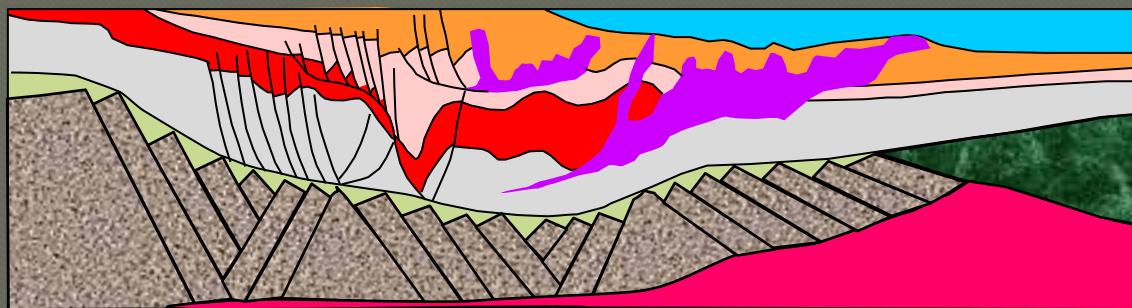
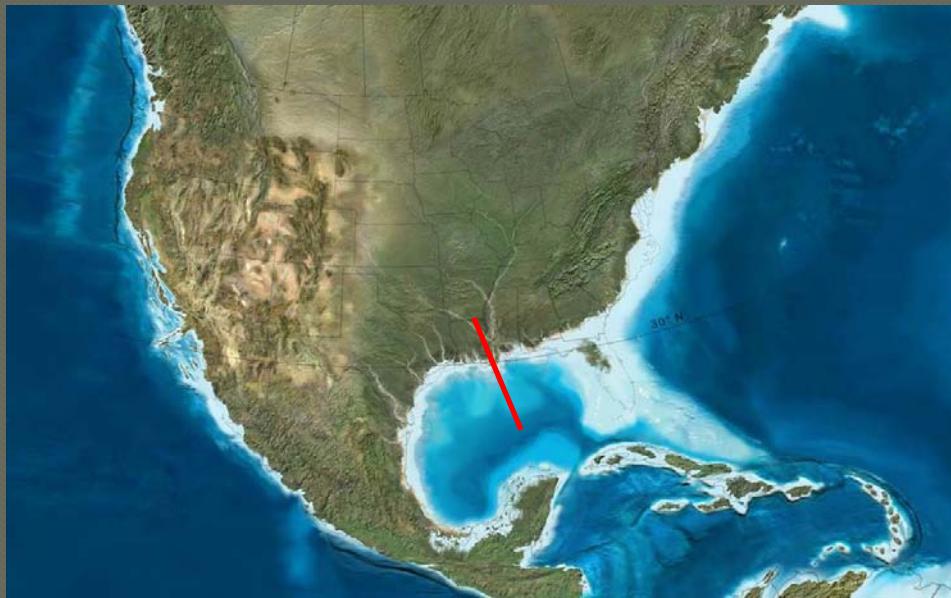
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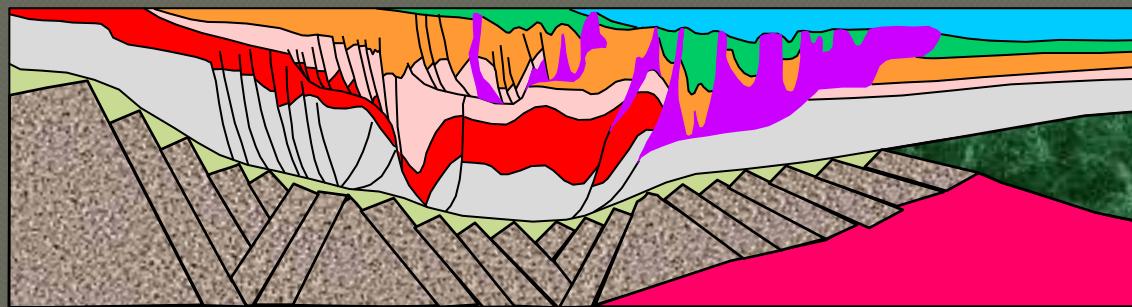
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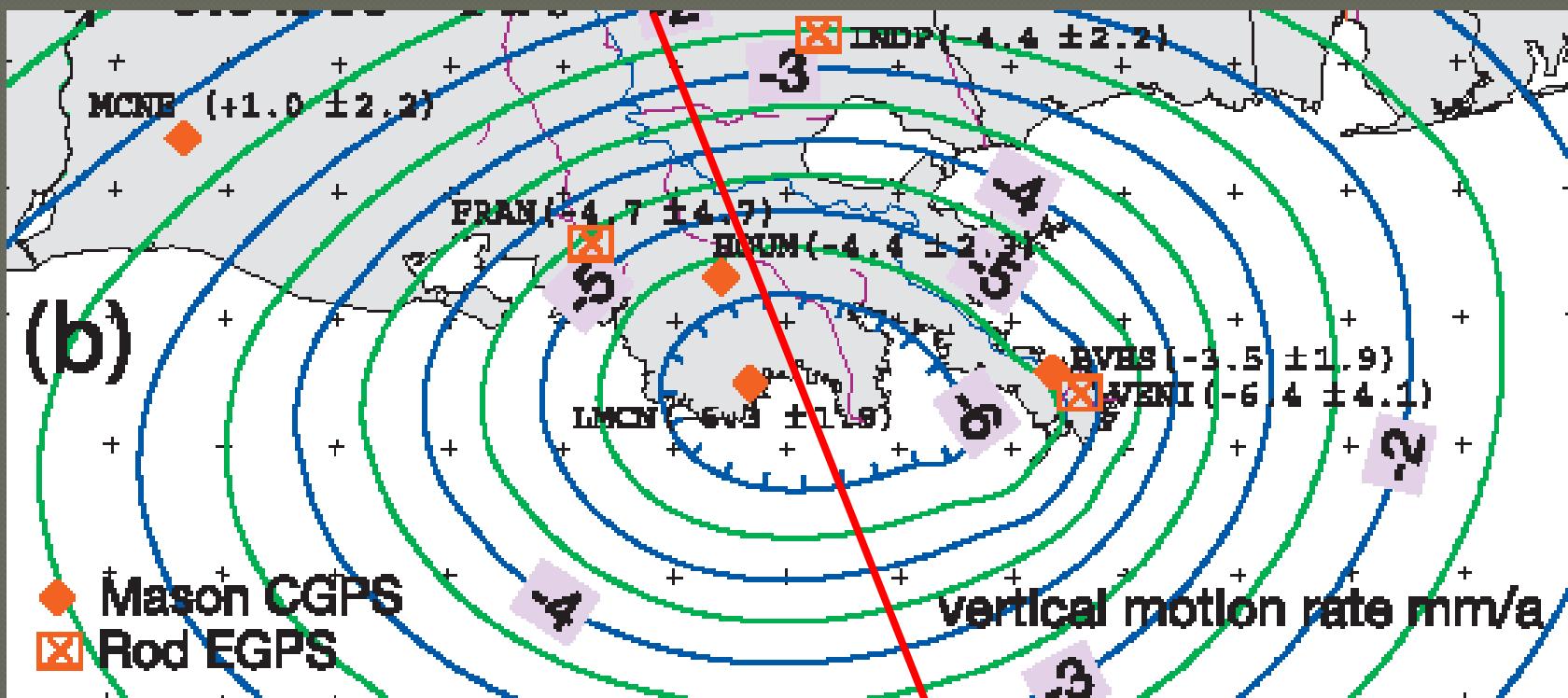


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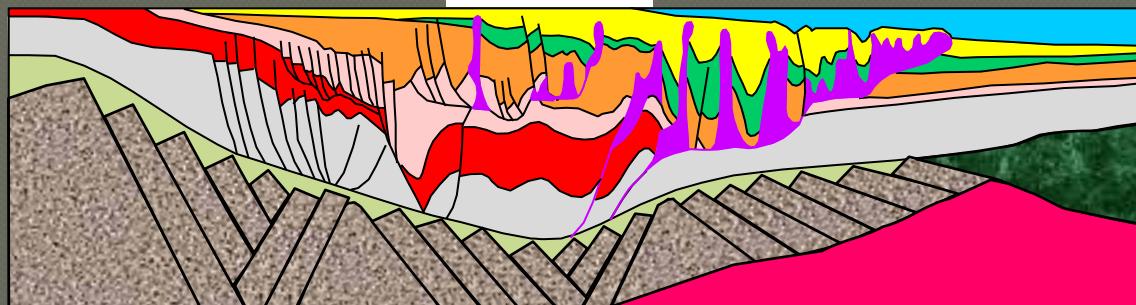


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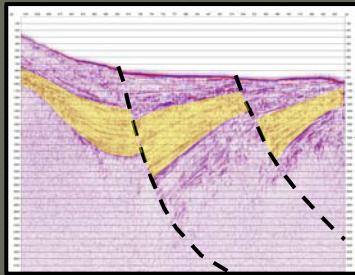


Coastal Louisiana

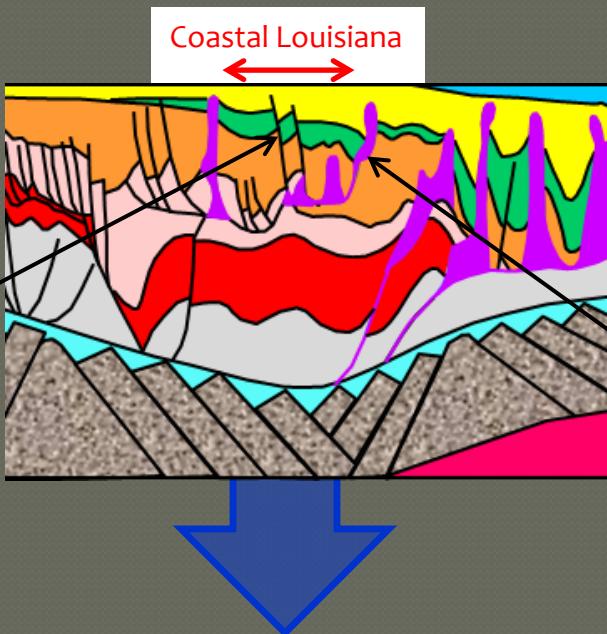


Mechanisms of Subsidence

HOT SPOT

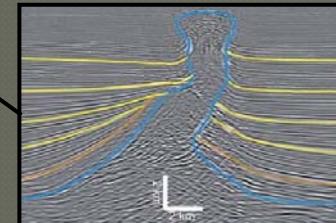


Lystric Faulting

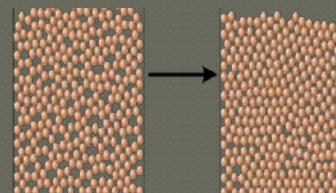


BACKGROUND

Crustal downwarp

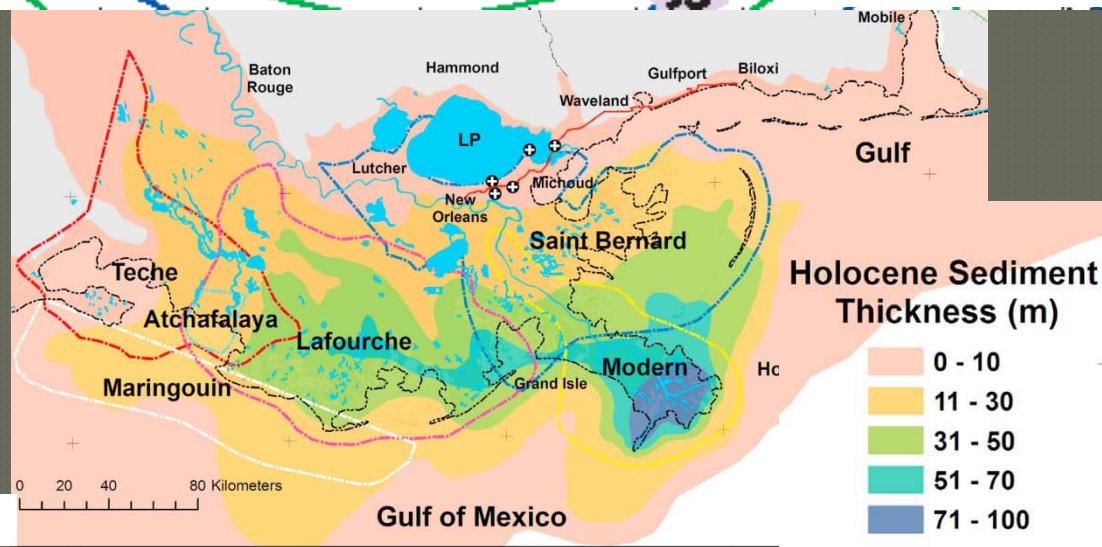
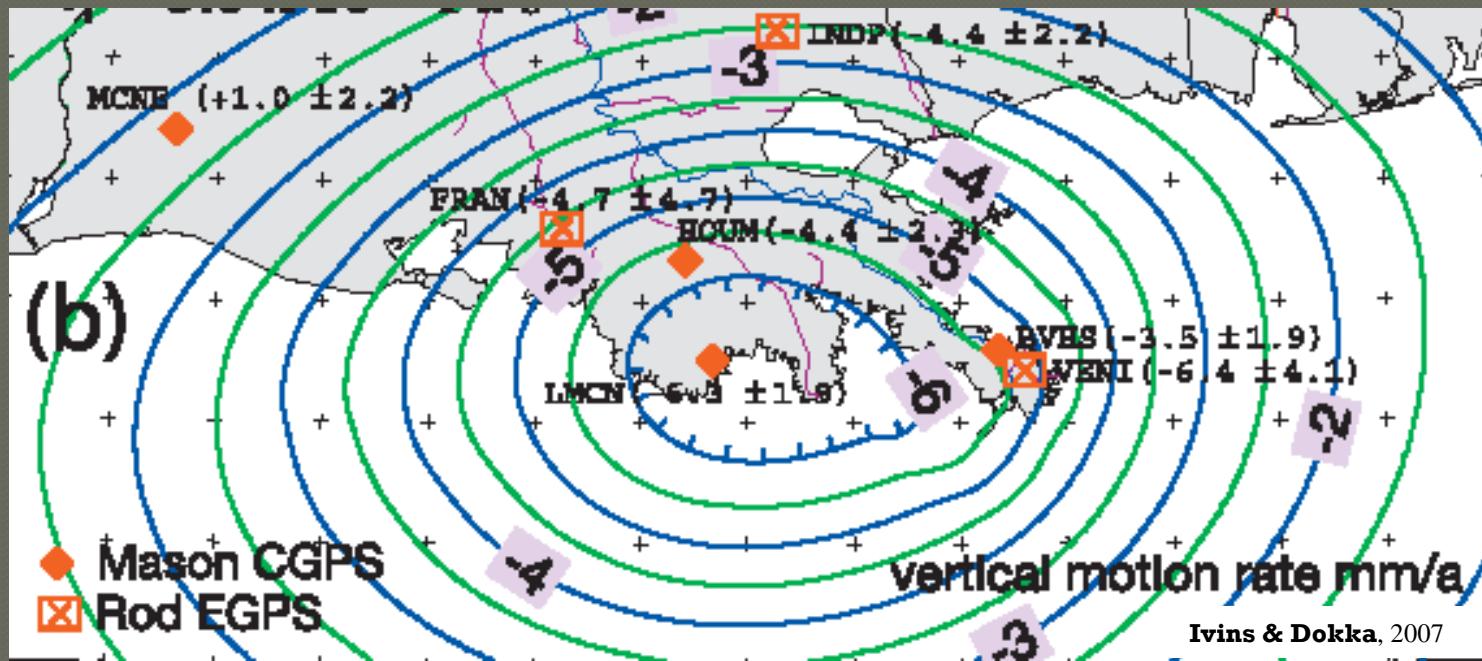


Lateral Salt Movement

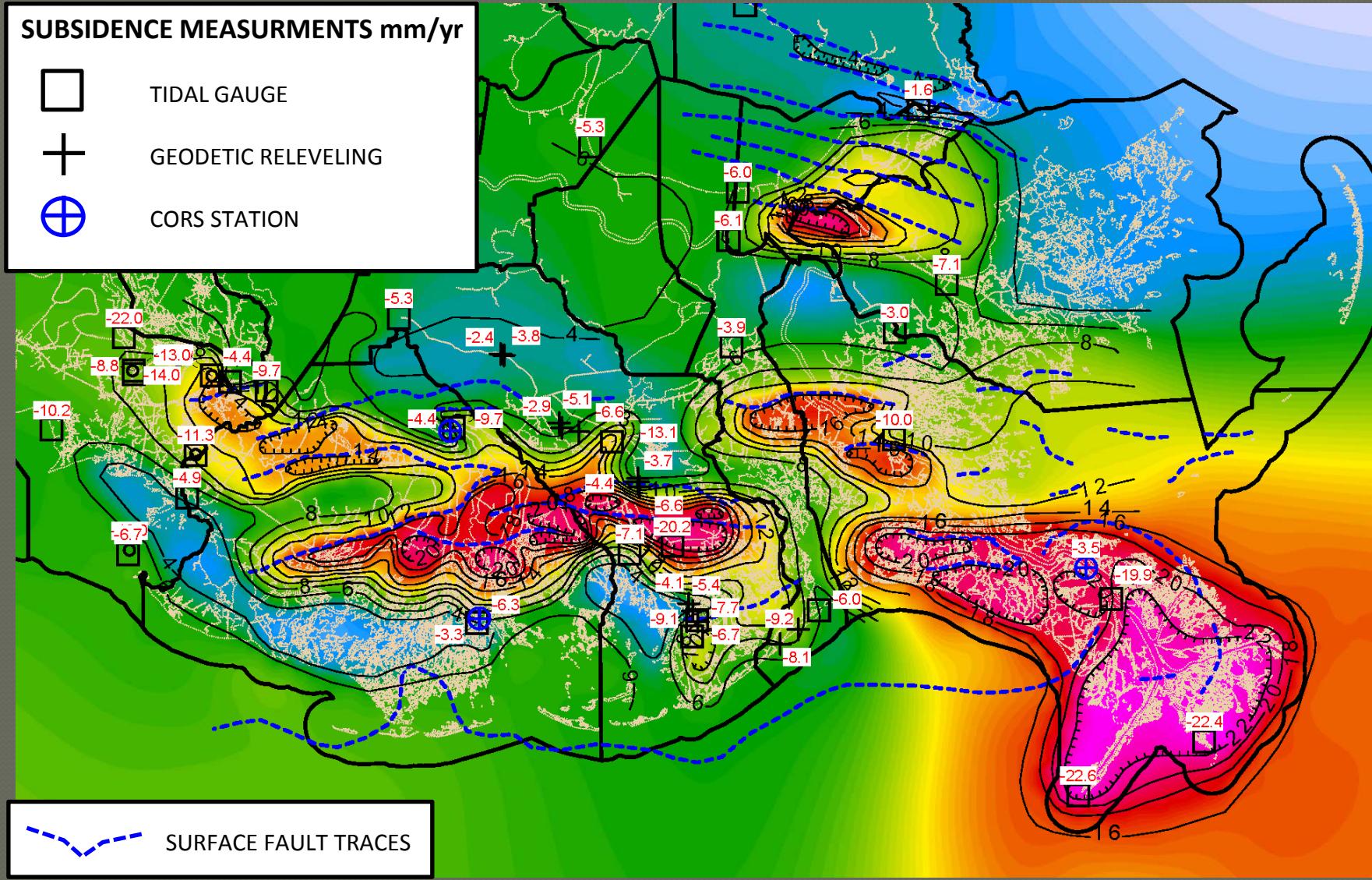


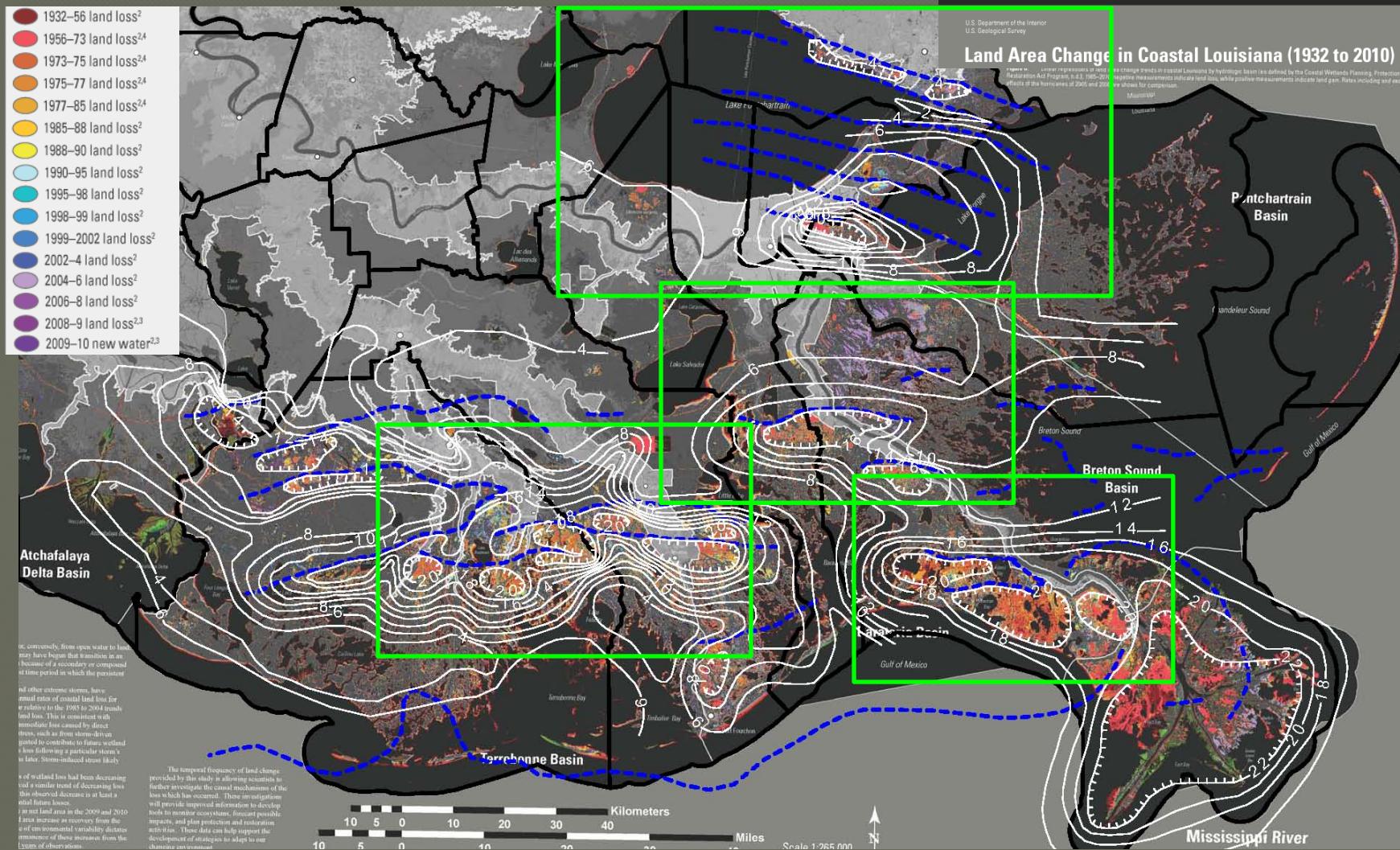
Sediment Compaction

Background Subsidence

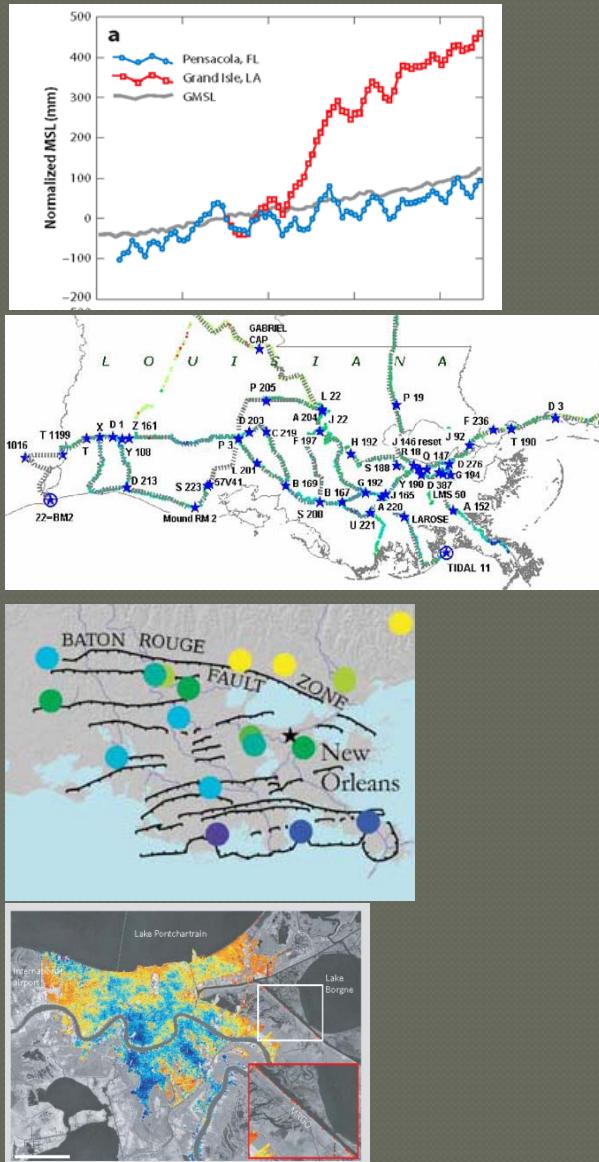


Hotspot Subsidence





Measuring Subsidence



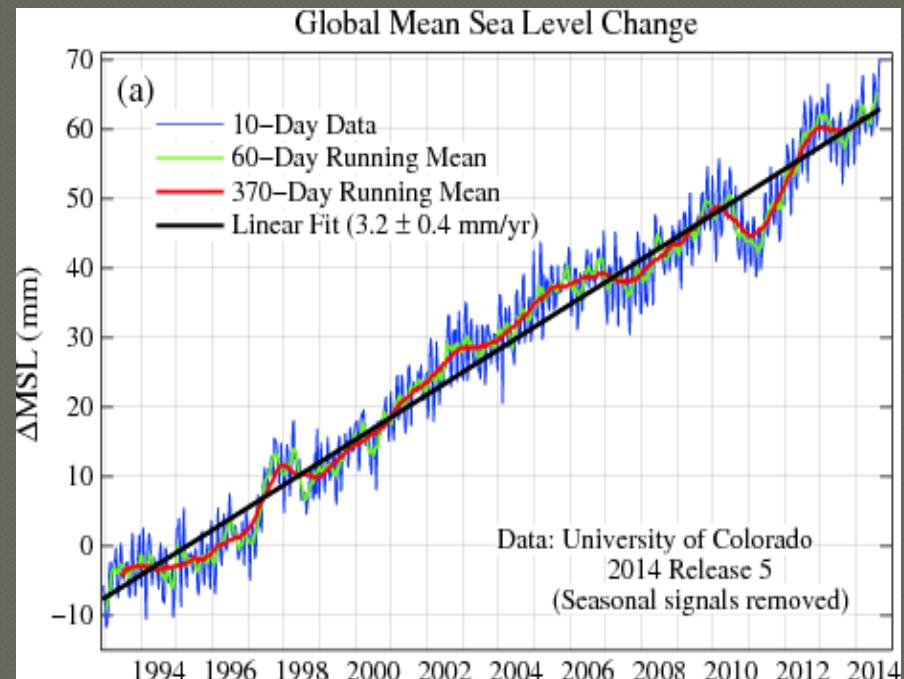
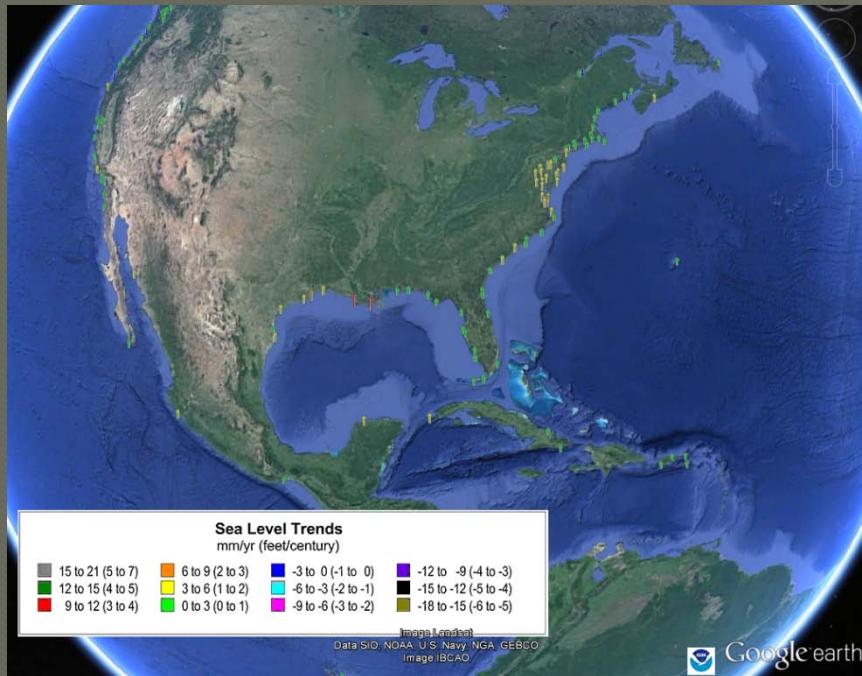
Historical Tidal Gauge Data

Geodetic Leveling

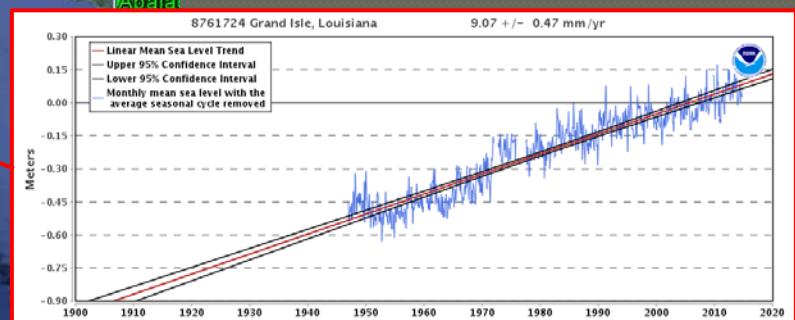
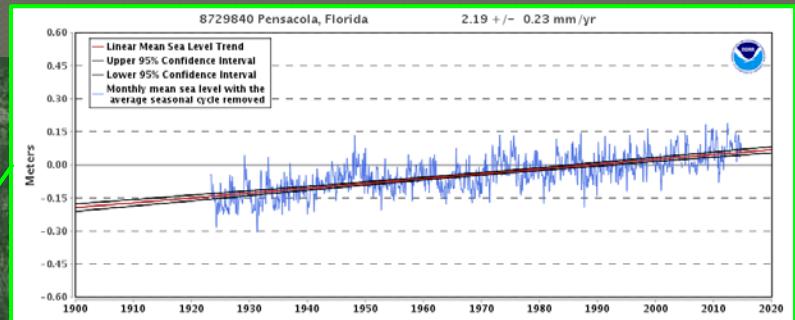
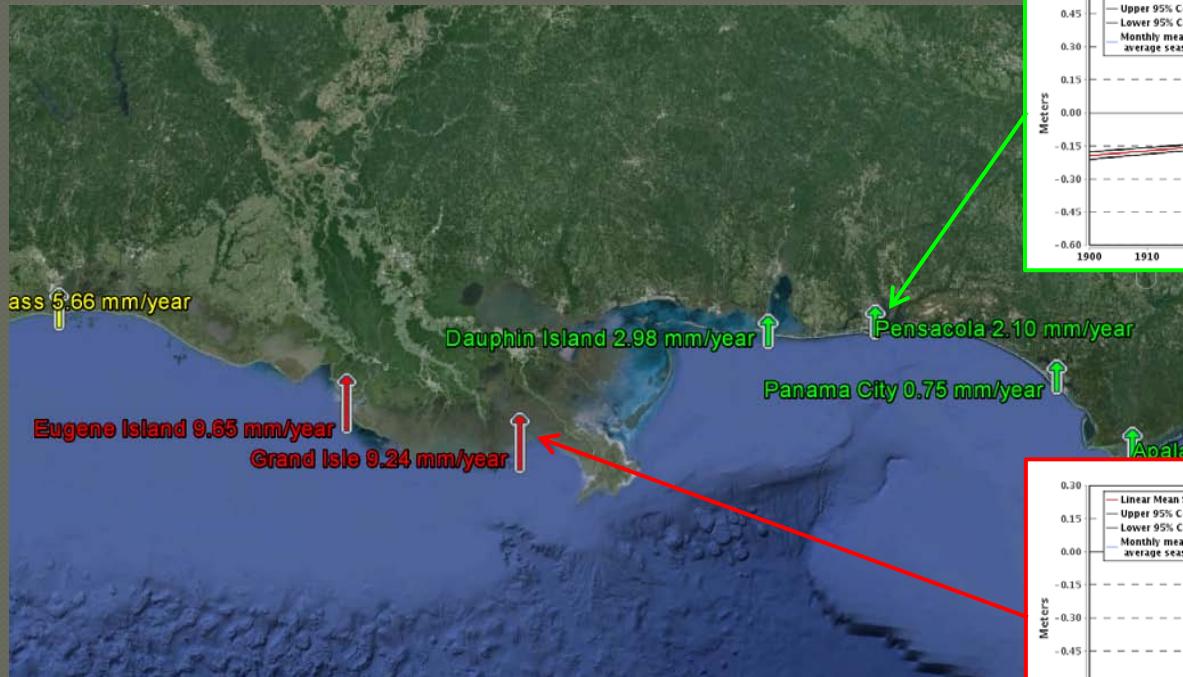
GPS – CORS Stations

InSAR Satellite Imagery

Subsidence and Sea Level Rise



Relative Sea Level Rise



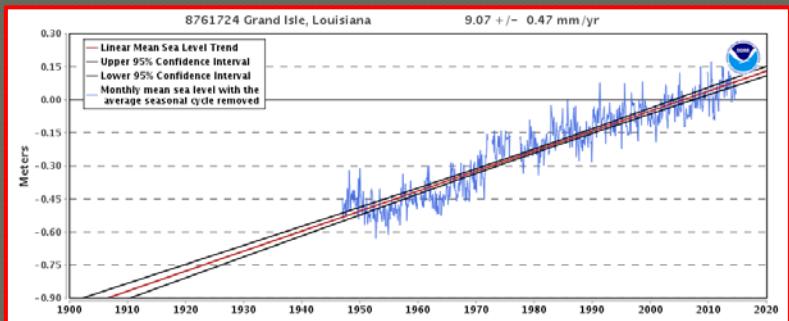
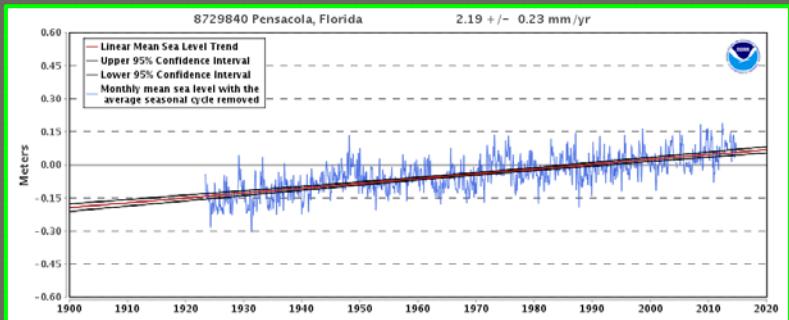
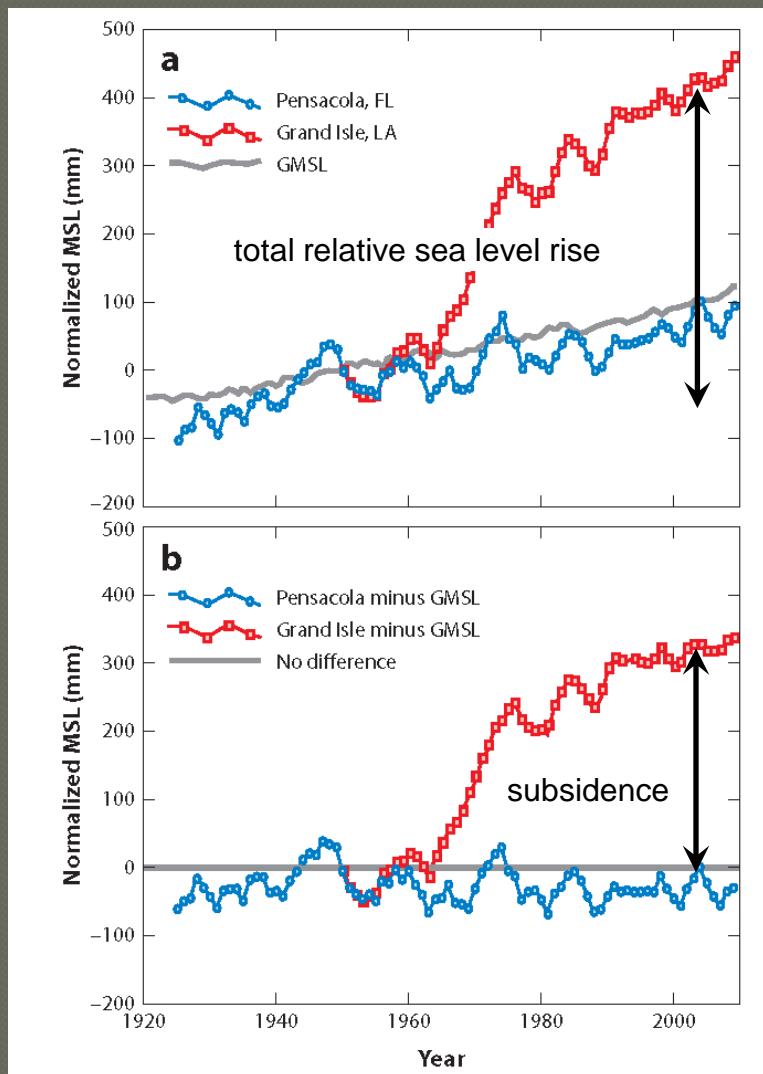
Sea Level Trends
mm/yr (feet/century)

15 to 21 (5 to 7)	6 to 9 (2 to 3)	-3 to 0 (-1 to 0)	-12 to -9 (-4 to -3)
12 to 15 (4 to 5)	3 to 6 (1 to 2)	-6 to -3 (-2 to -1)	-15 to -12 (-5 to -4)
9 to 12 (3 to 4)	0 to 3 (0 to 1)	-9 to -6 (-3 to -2)	-18 to -15 (-6 to -5)

Image: Landsat
Data: SIO, NOAA, U.S. Navy, NGA, GEBCO

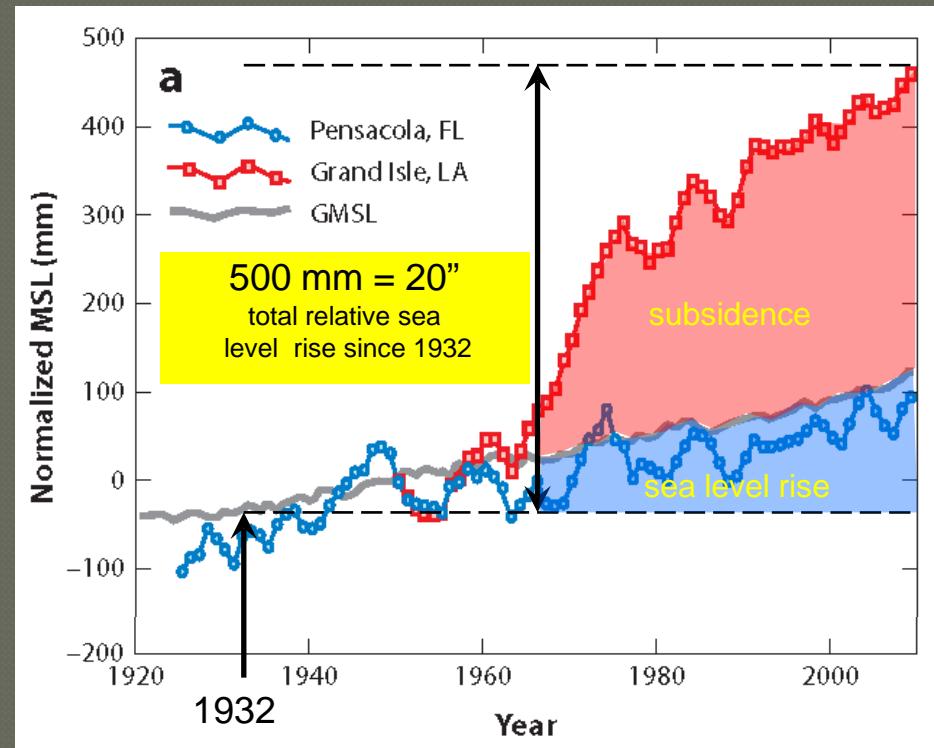
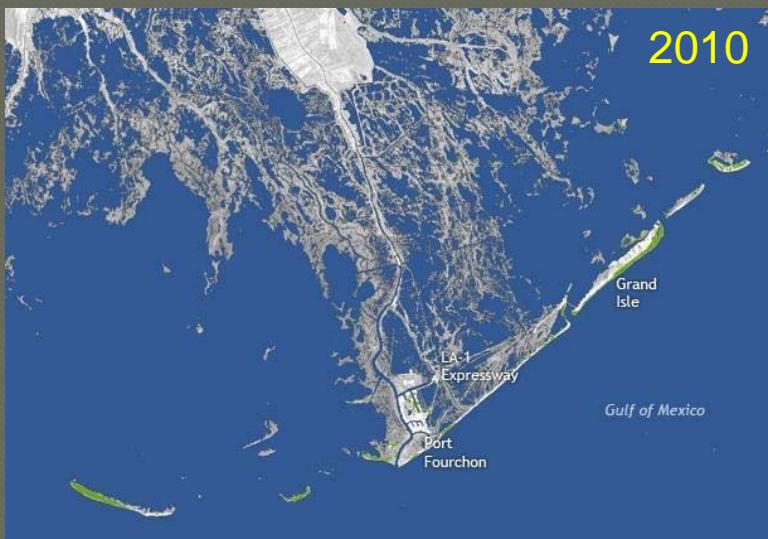
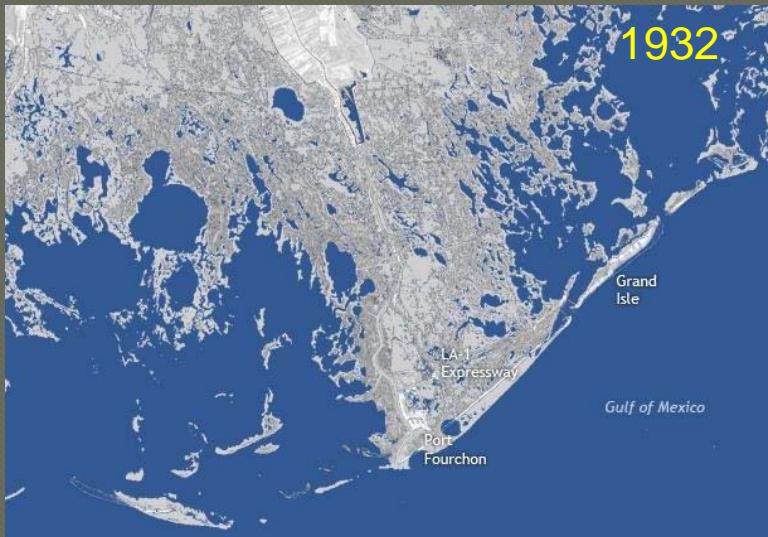
Google earth

Subsidence and Sea Level Rise

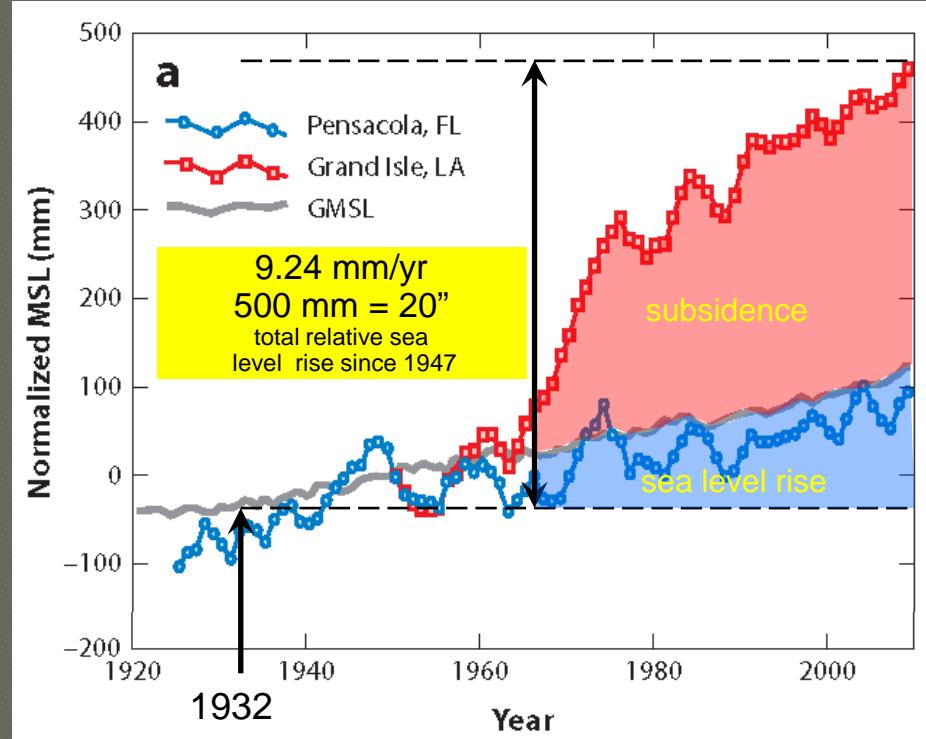
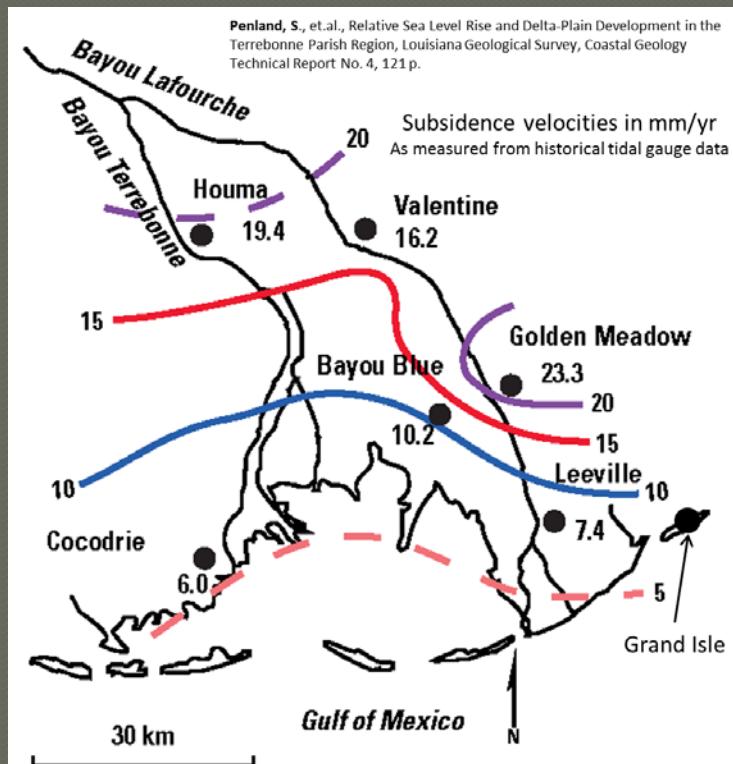


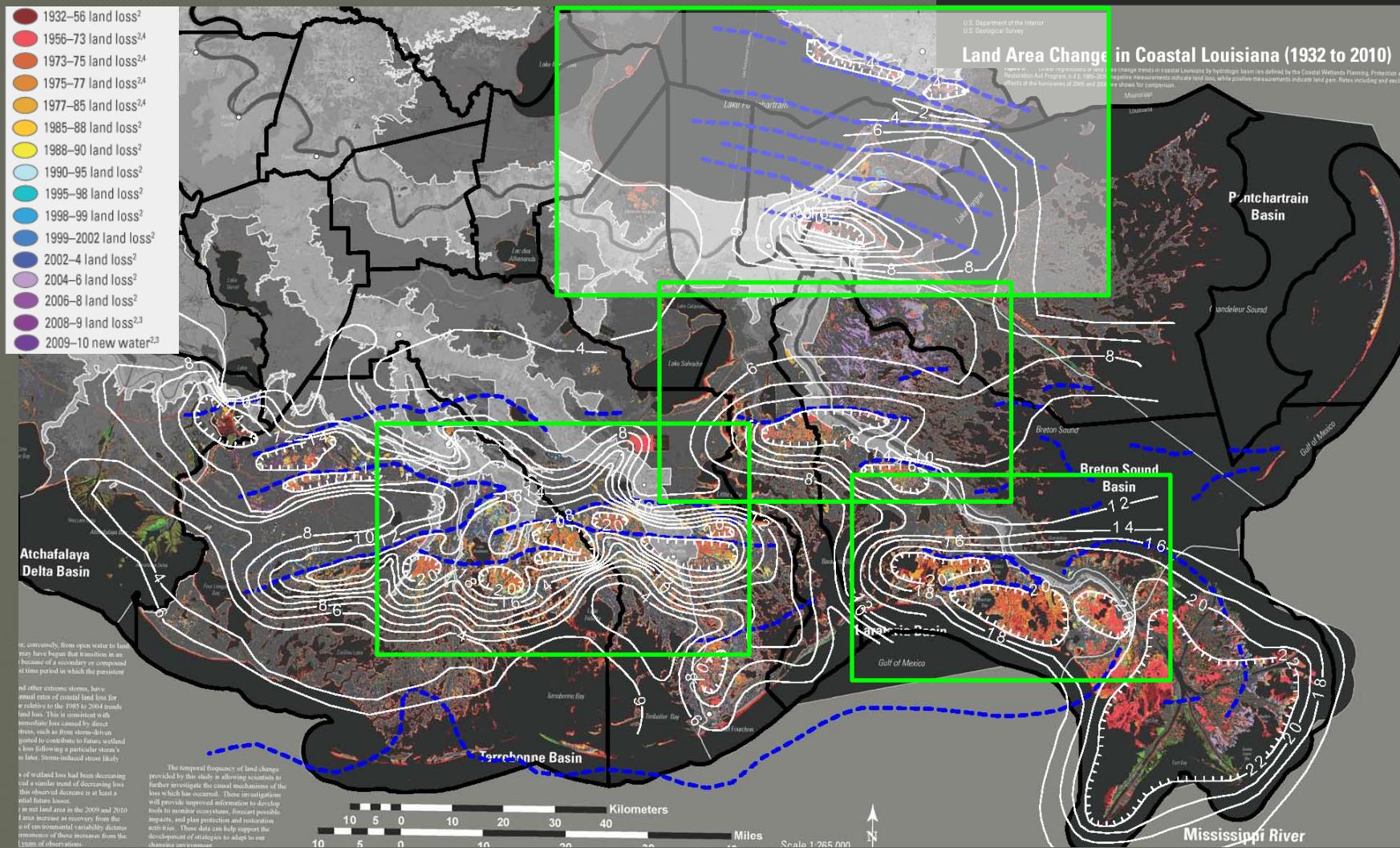
Blum, M.D. and Roberts, H.H., 2012, The Mississippi Delta Region: Past, Present, and Future, Annual Review of Earth and Planetary Sciences, v. 40, p. 655-683

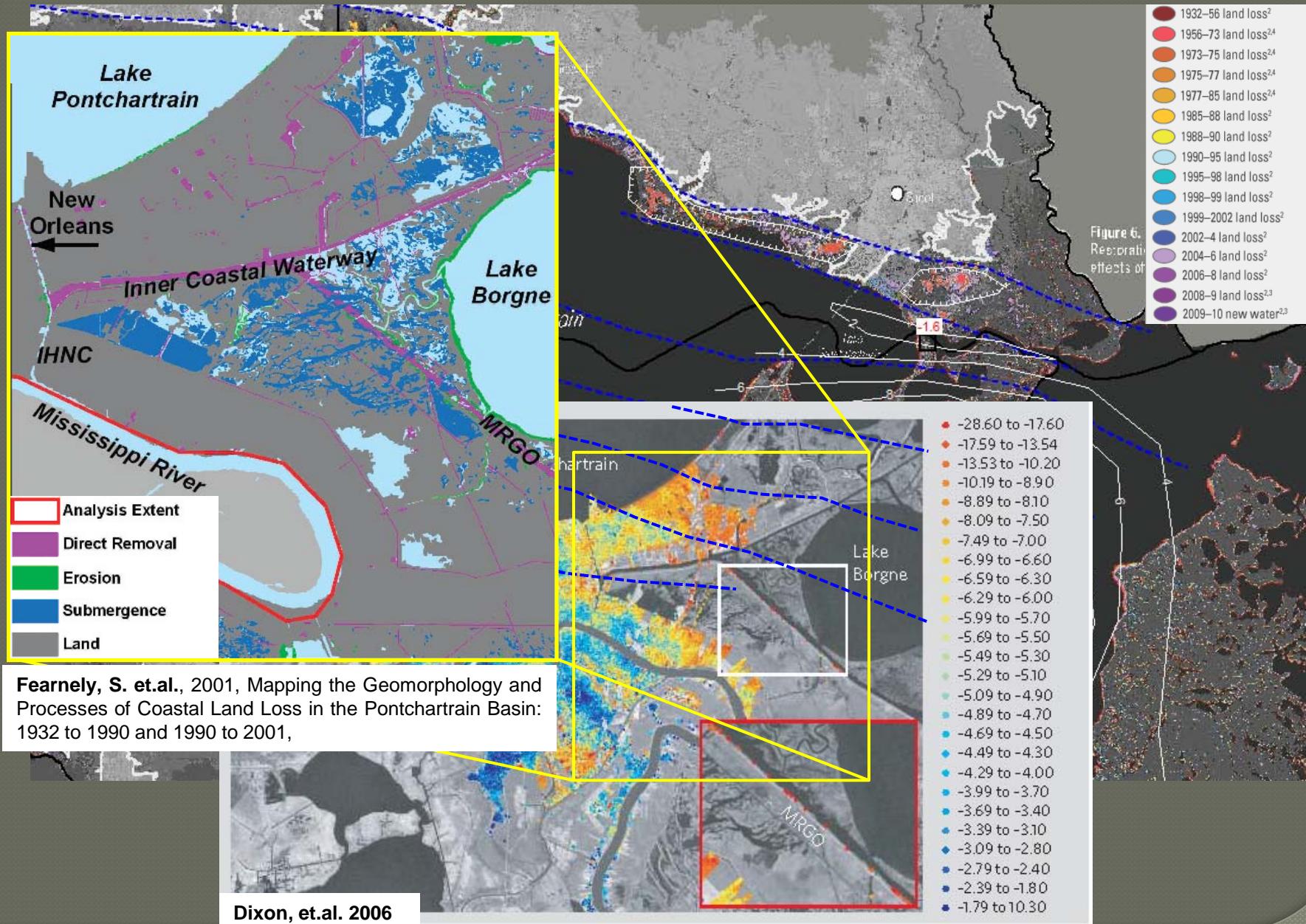
78 years of Submergence

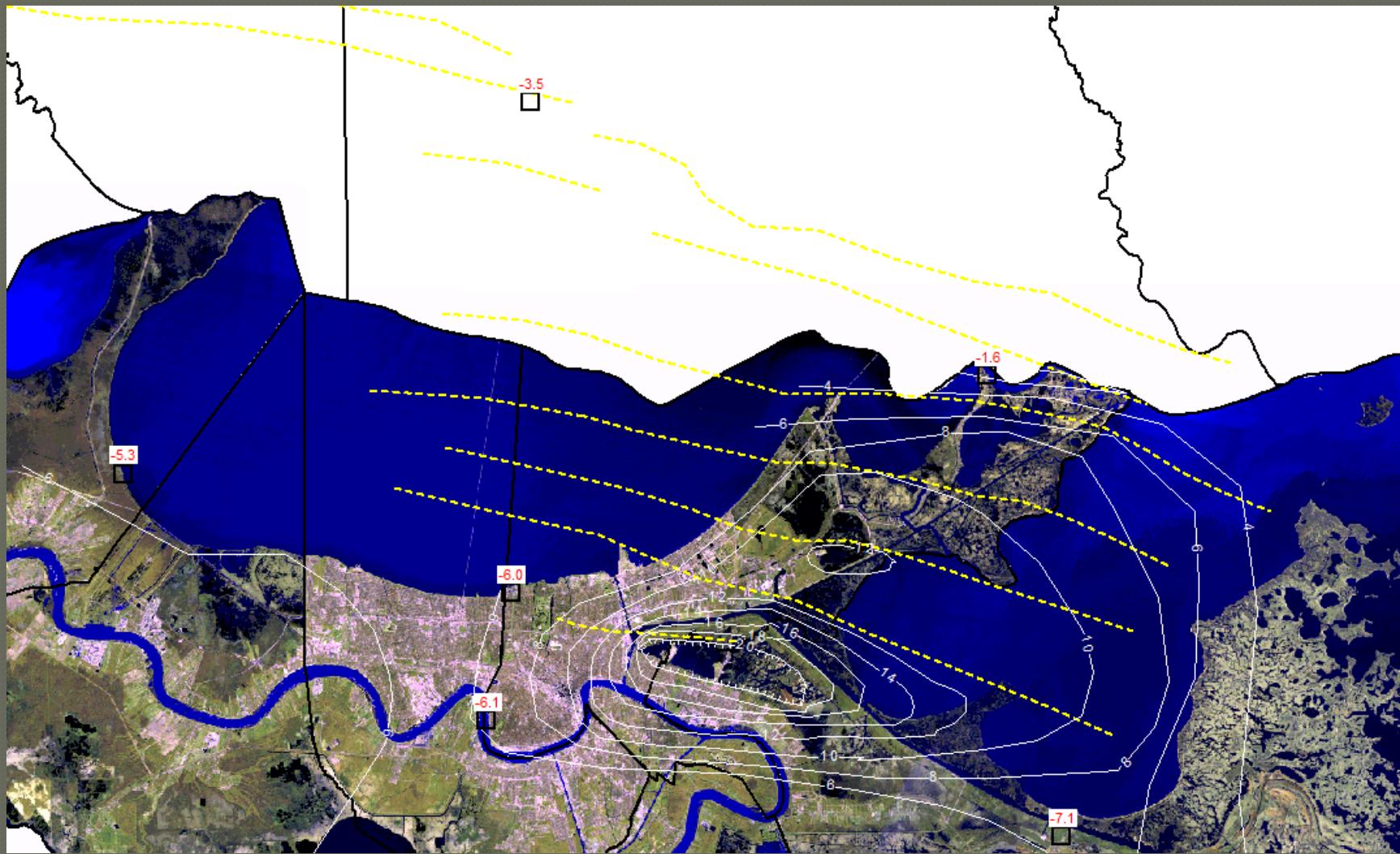


Subsidence from Tidal Gauge Data

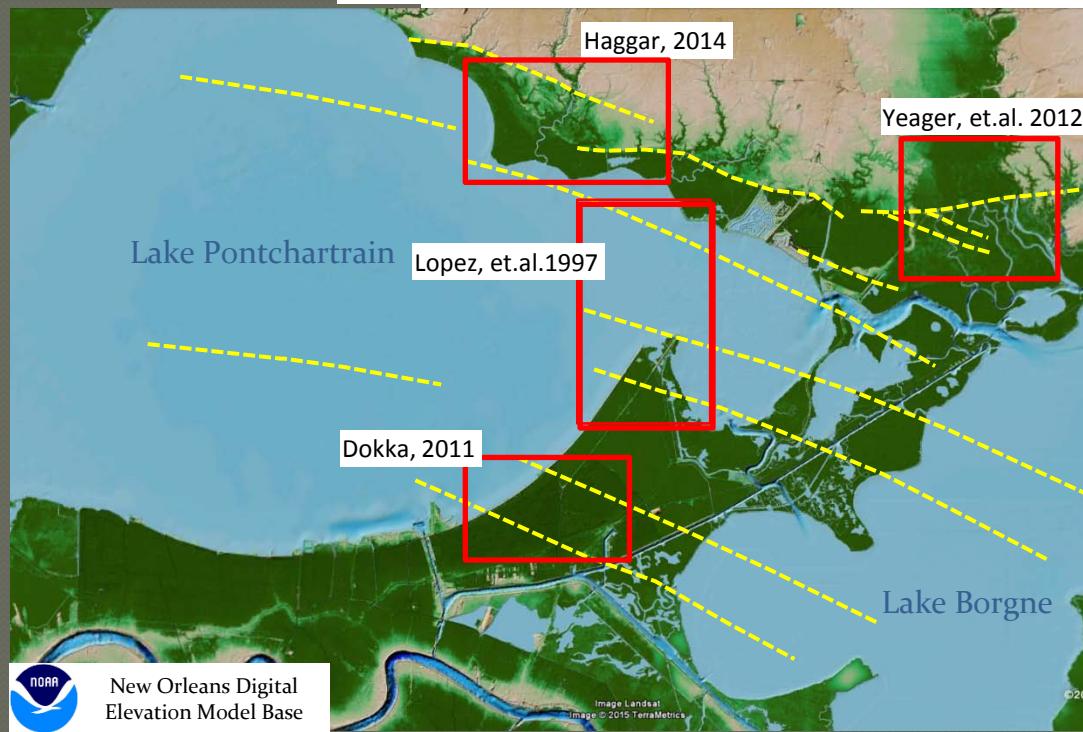
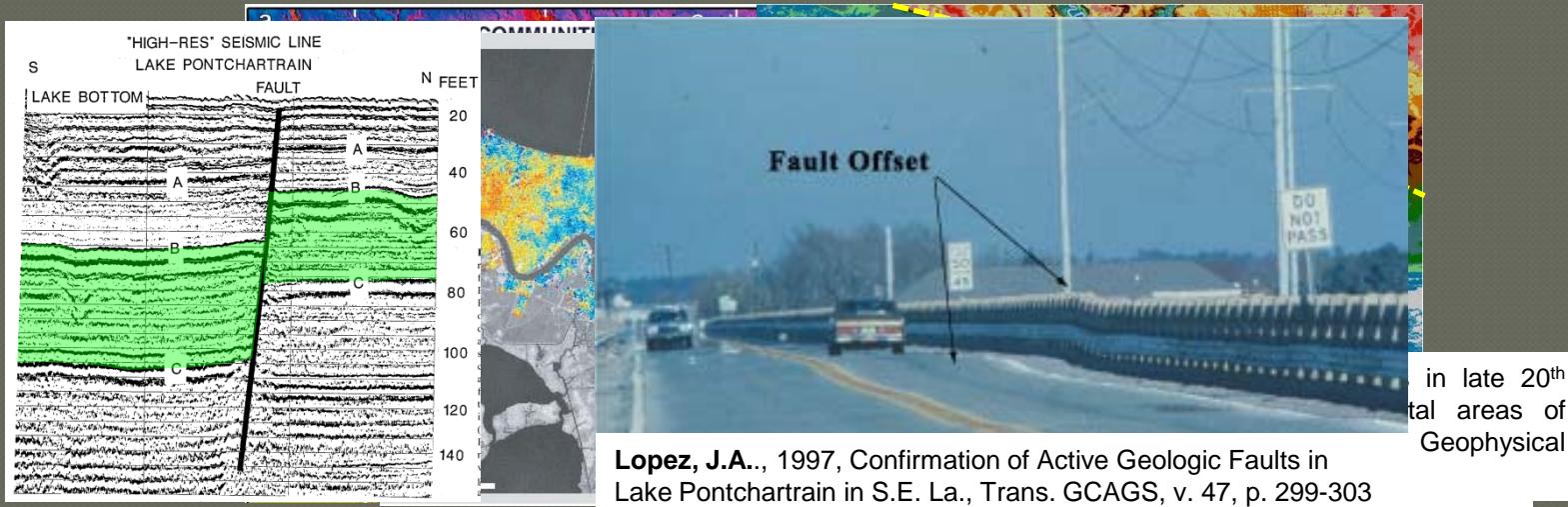








Subsidence and Faulting

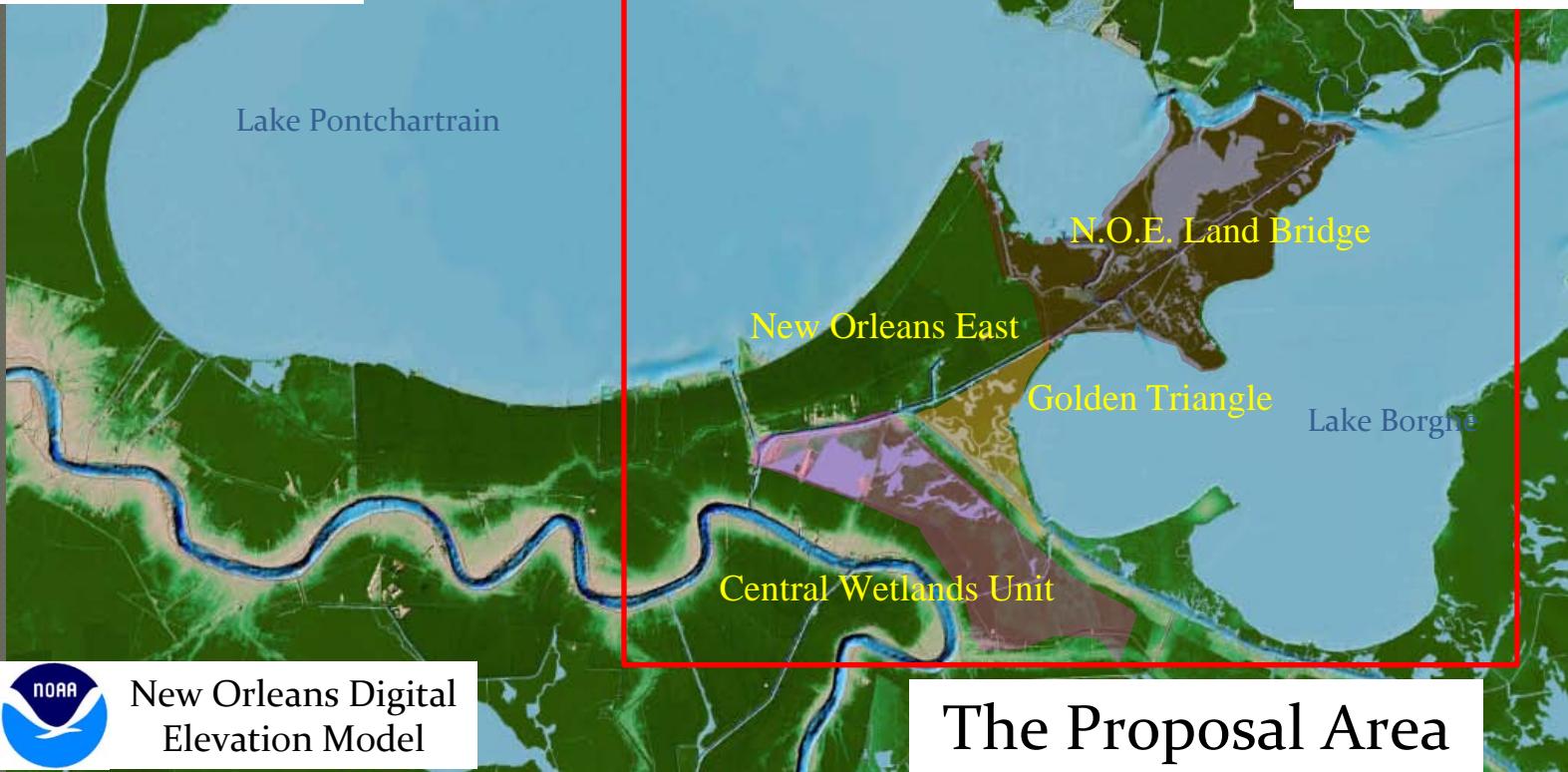


Cooperative Research Project



Pontchartrain
Institute for
Environmental
Sciences
University of New Orleans

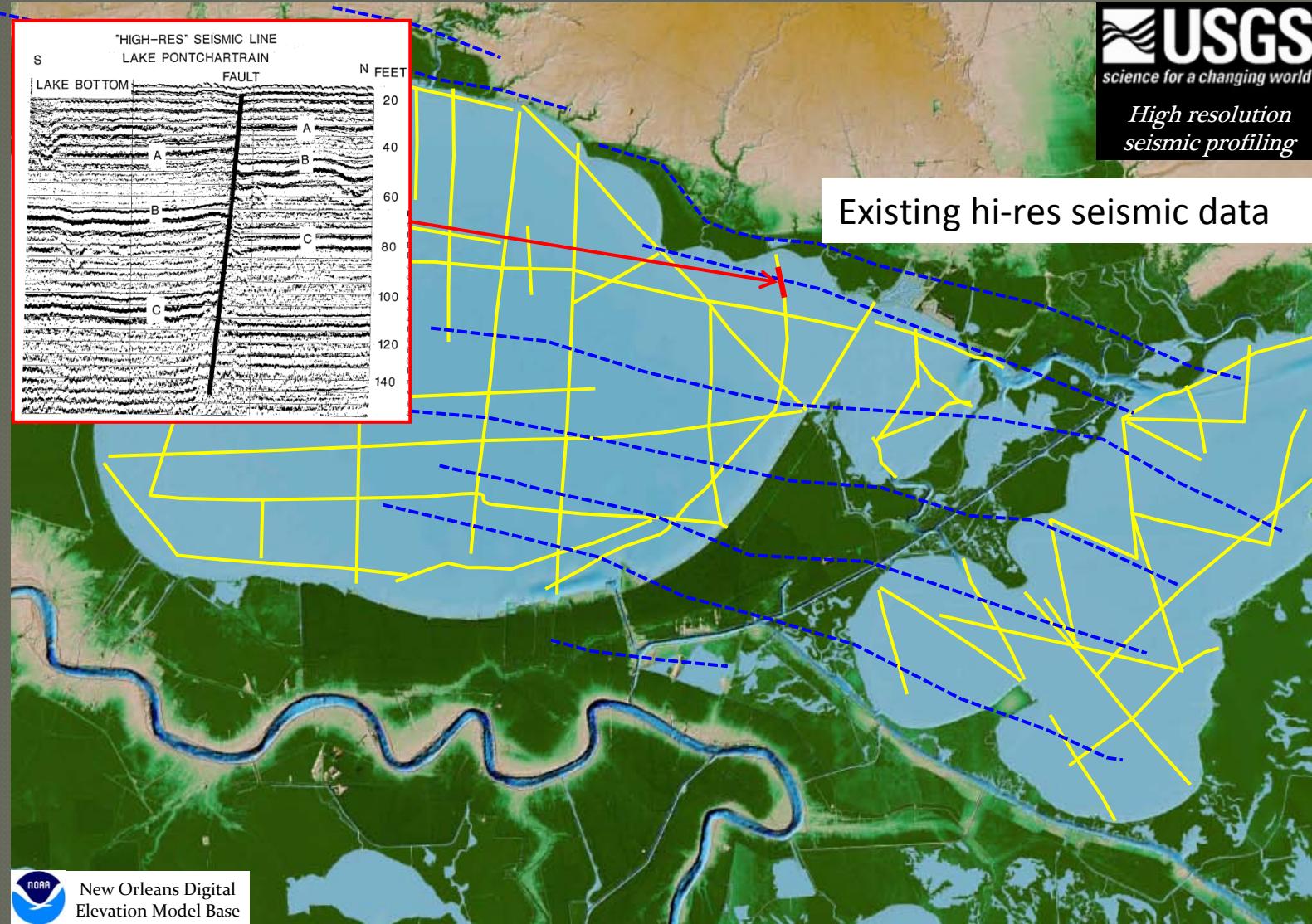
LAKE PONTCHARTRAIN
BASIN FOUNDATION
SAVE OUR COAST
SAVE OUR LAKE



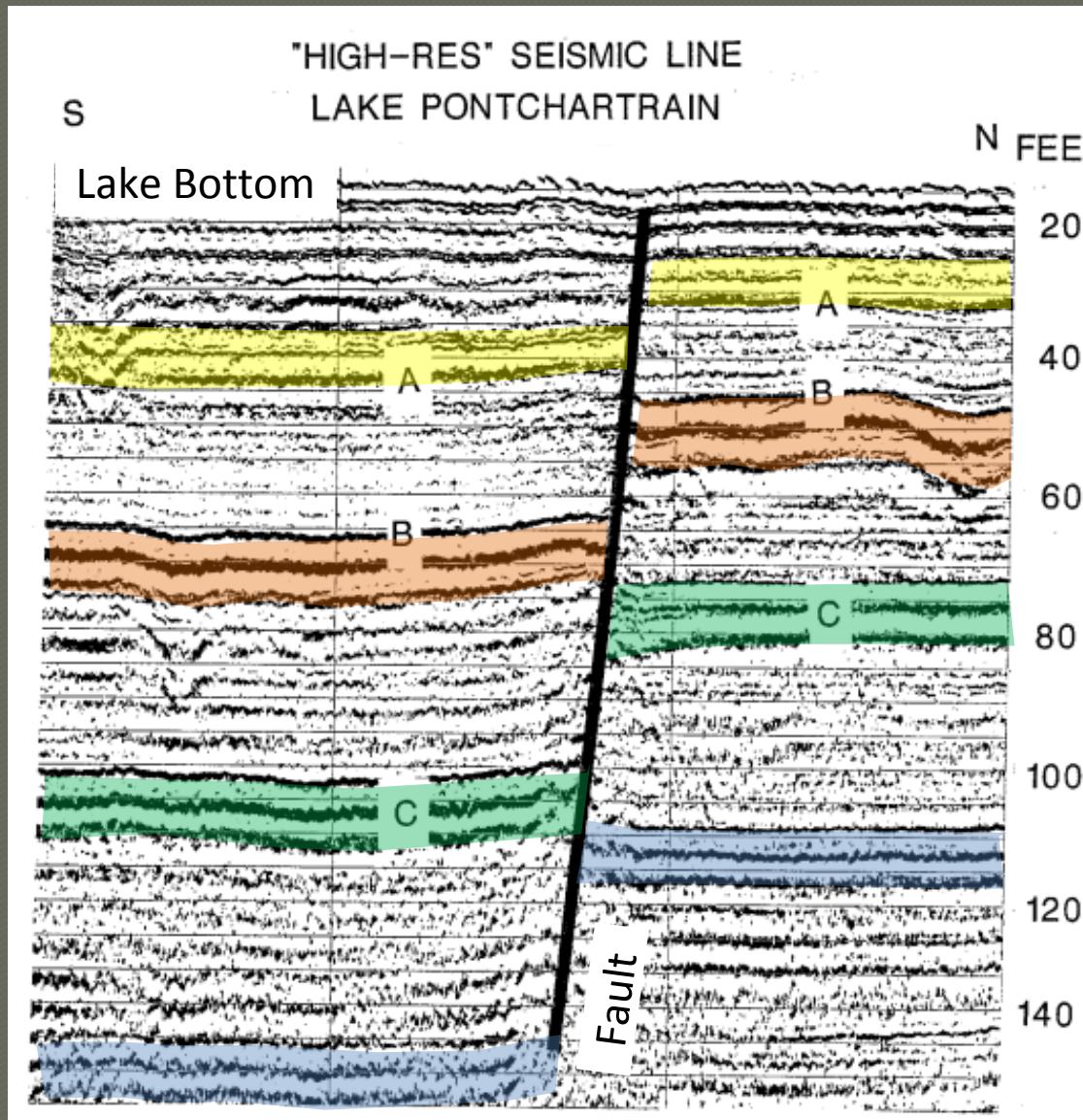
New Orleans Digital
Elevation Model

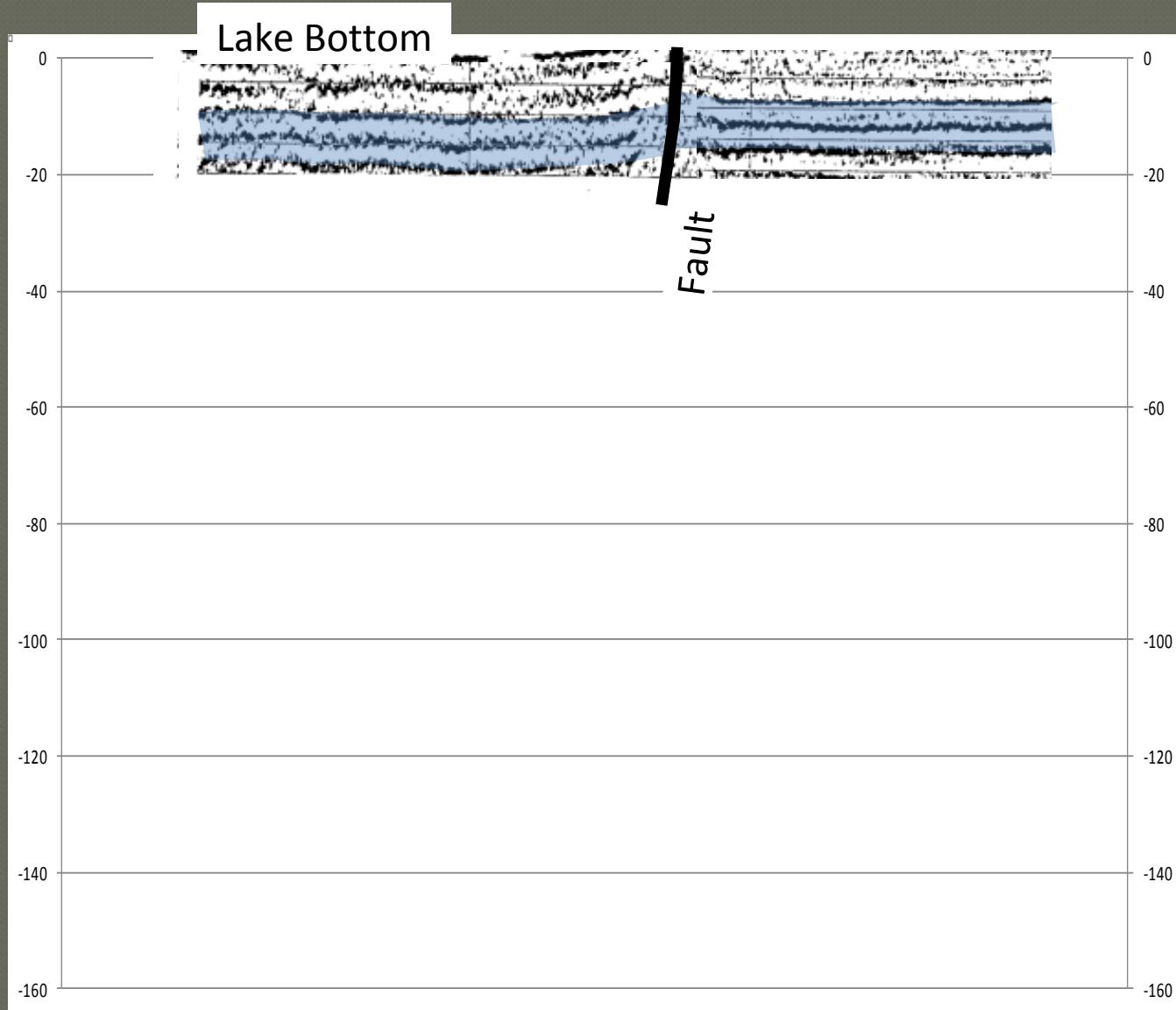


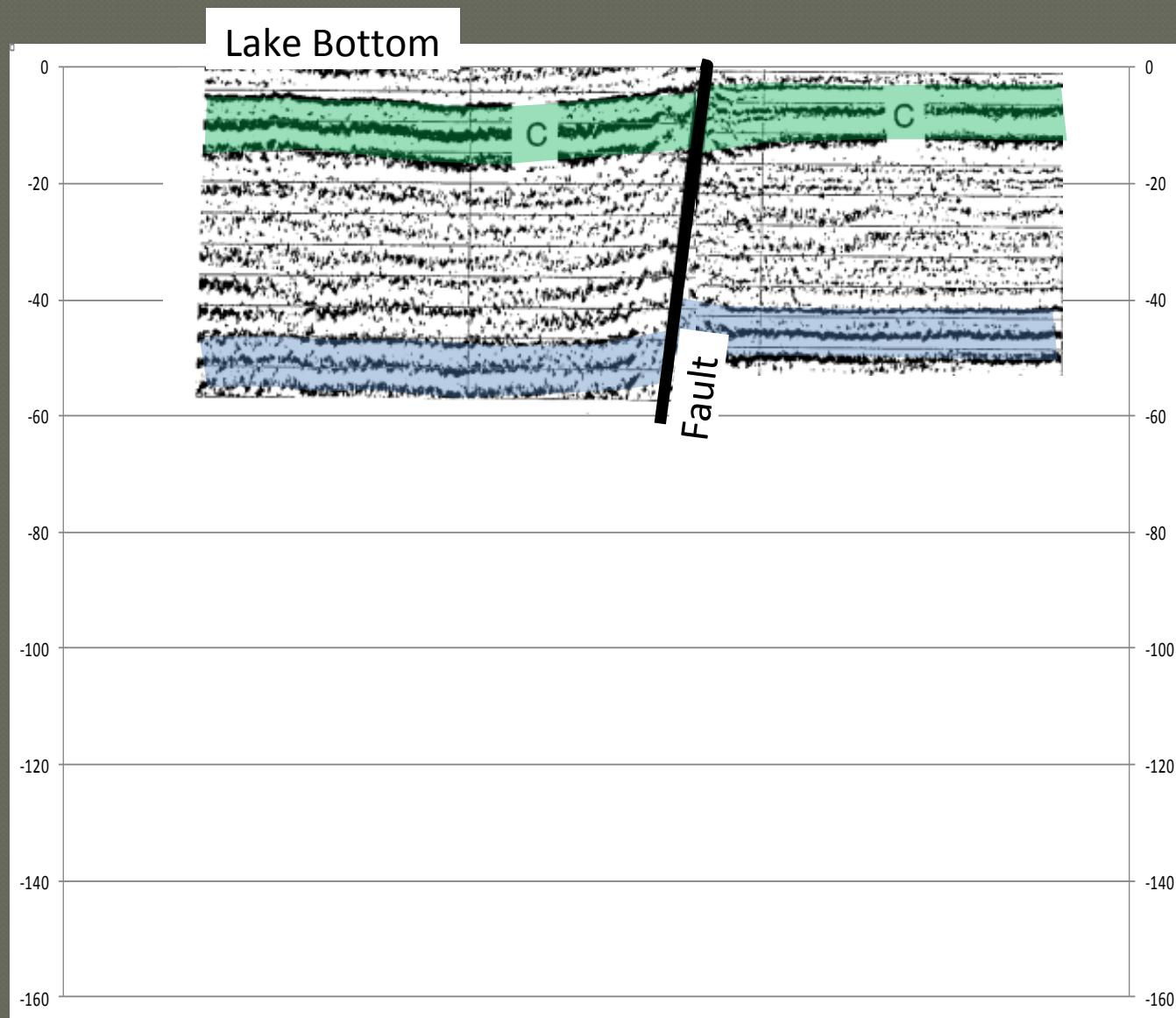
*High resolution
seismic profiling*

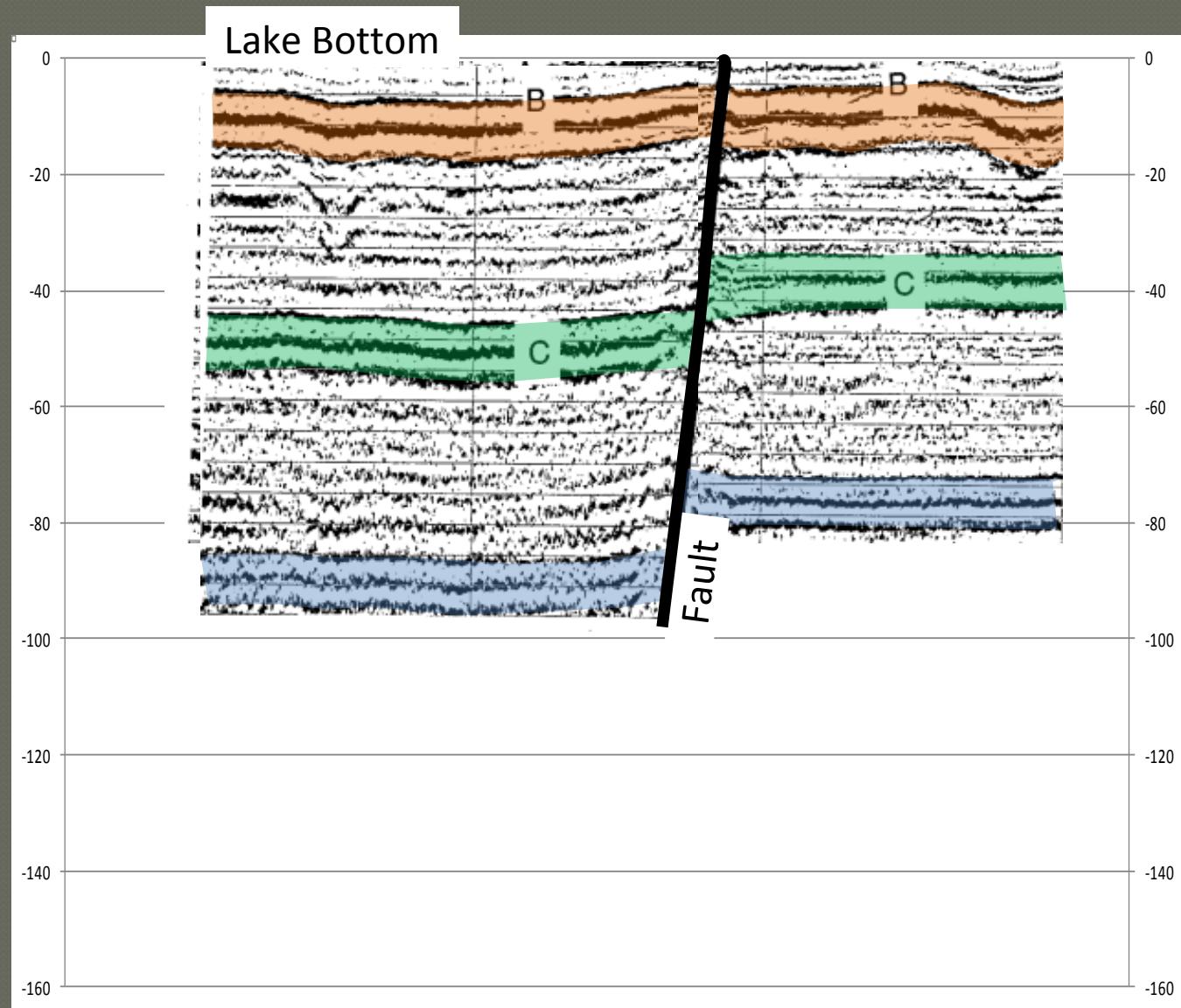


Subsidence and Faulting

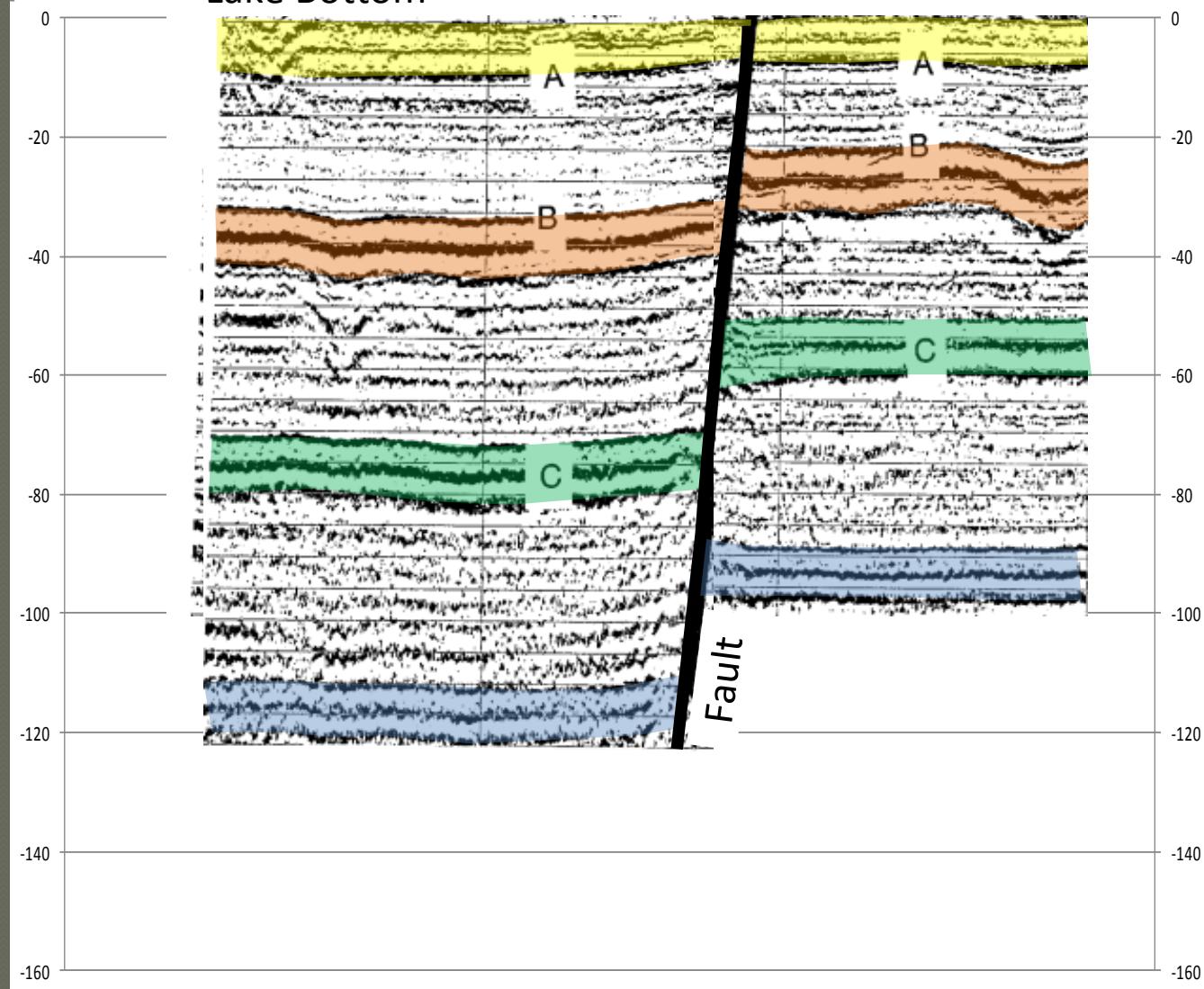


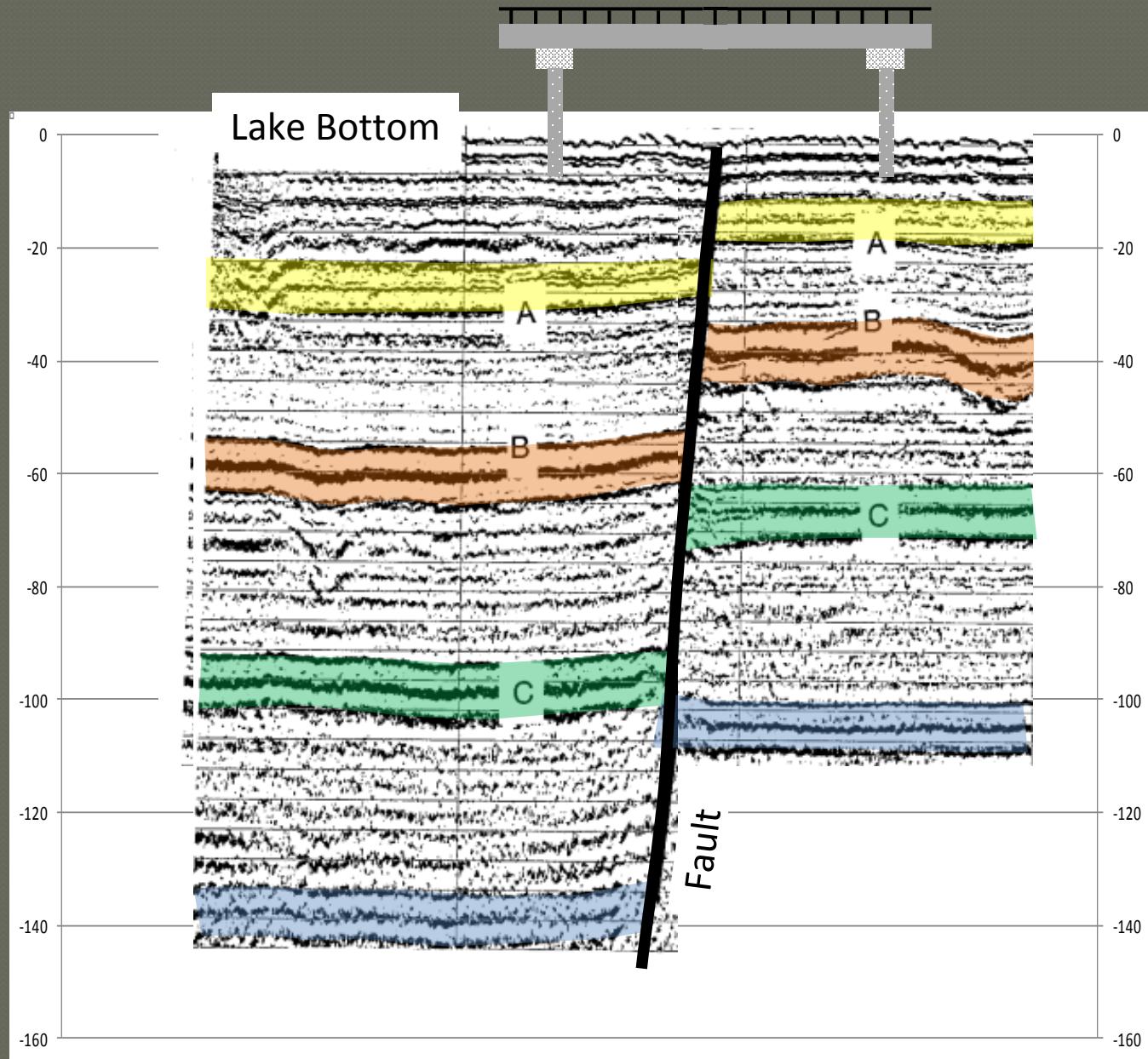


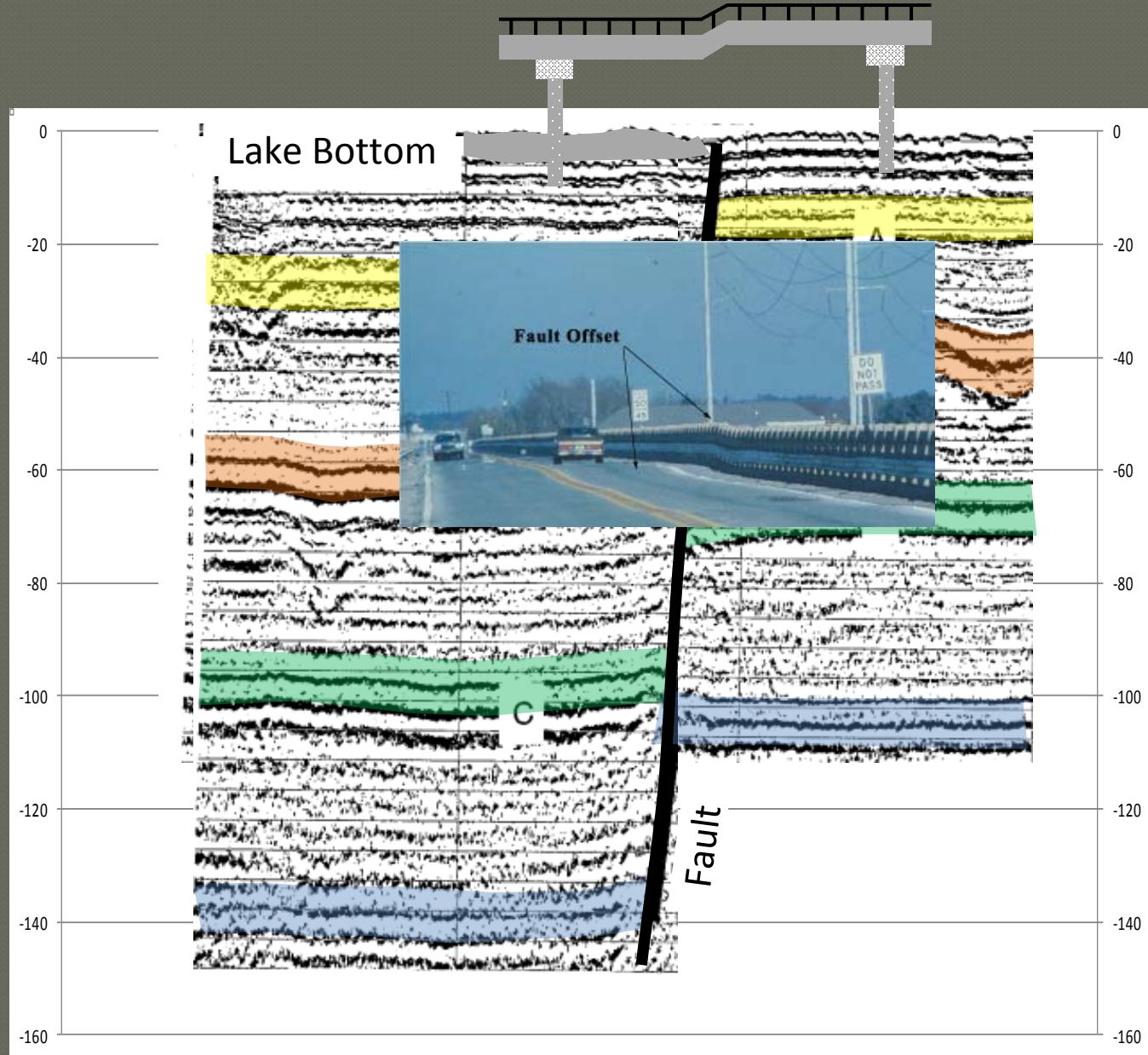




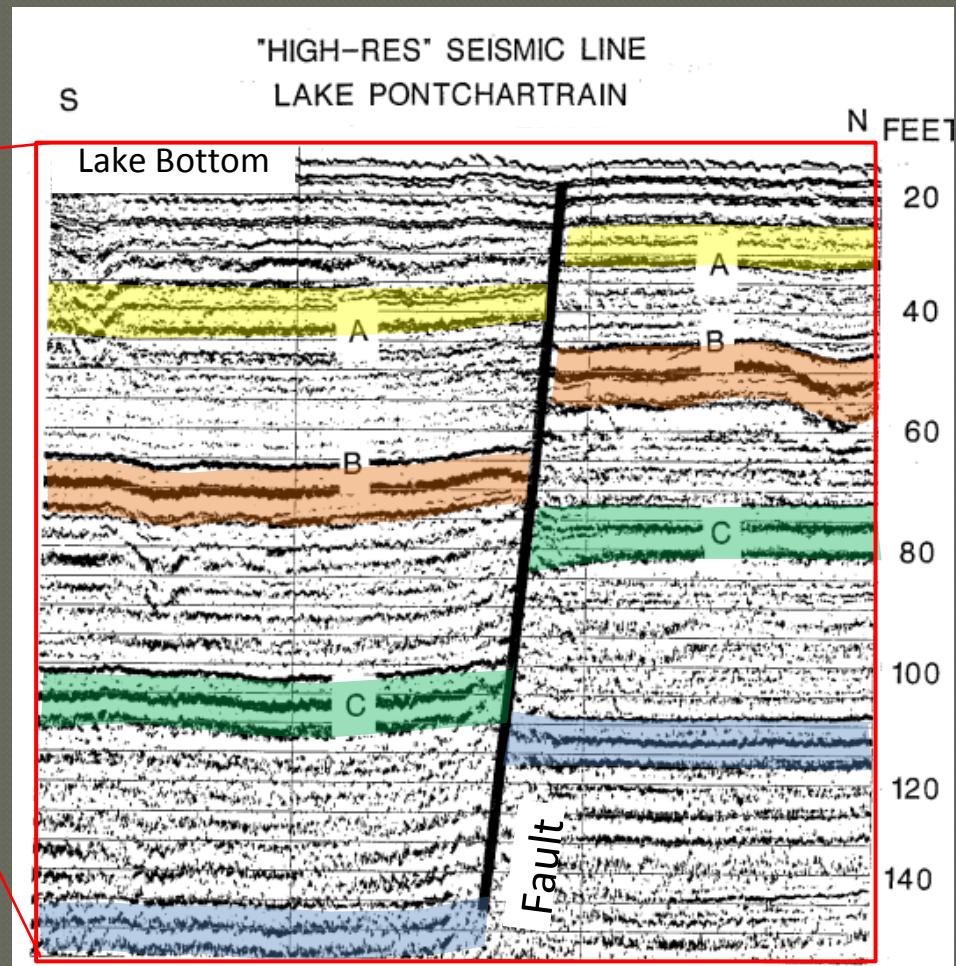
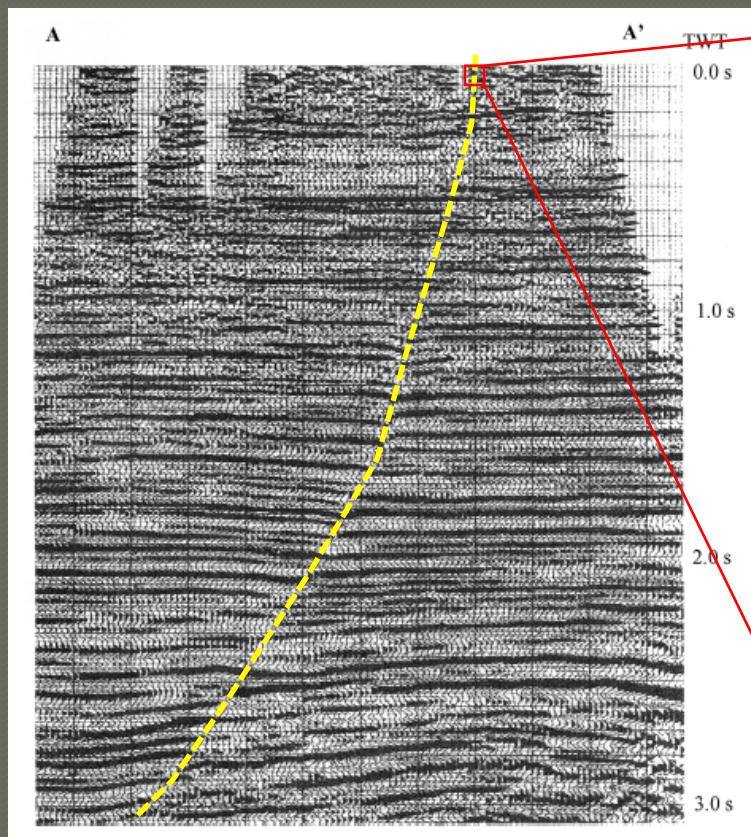
Lake Bottom







Hi-res seismic vs. Industry seismic

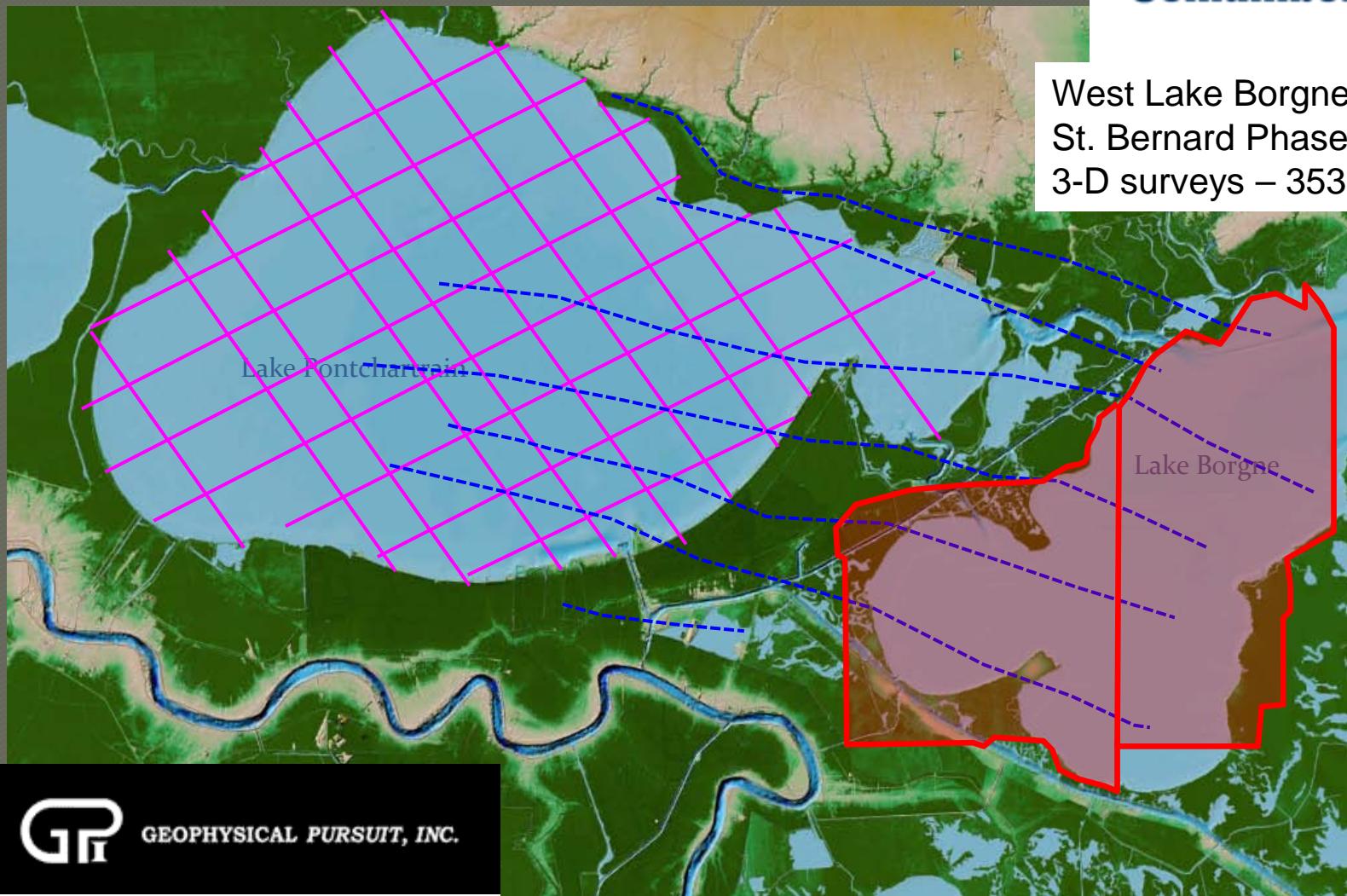


Project Phase I

interpret industry seismic

Schlumberger

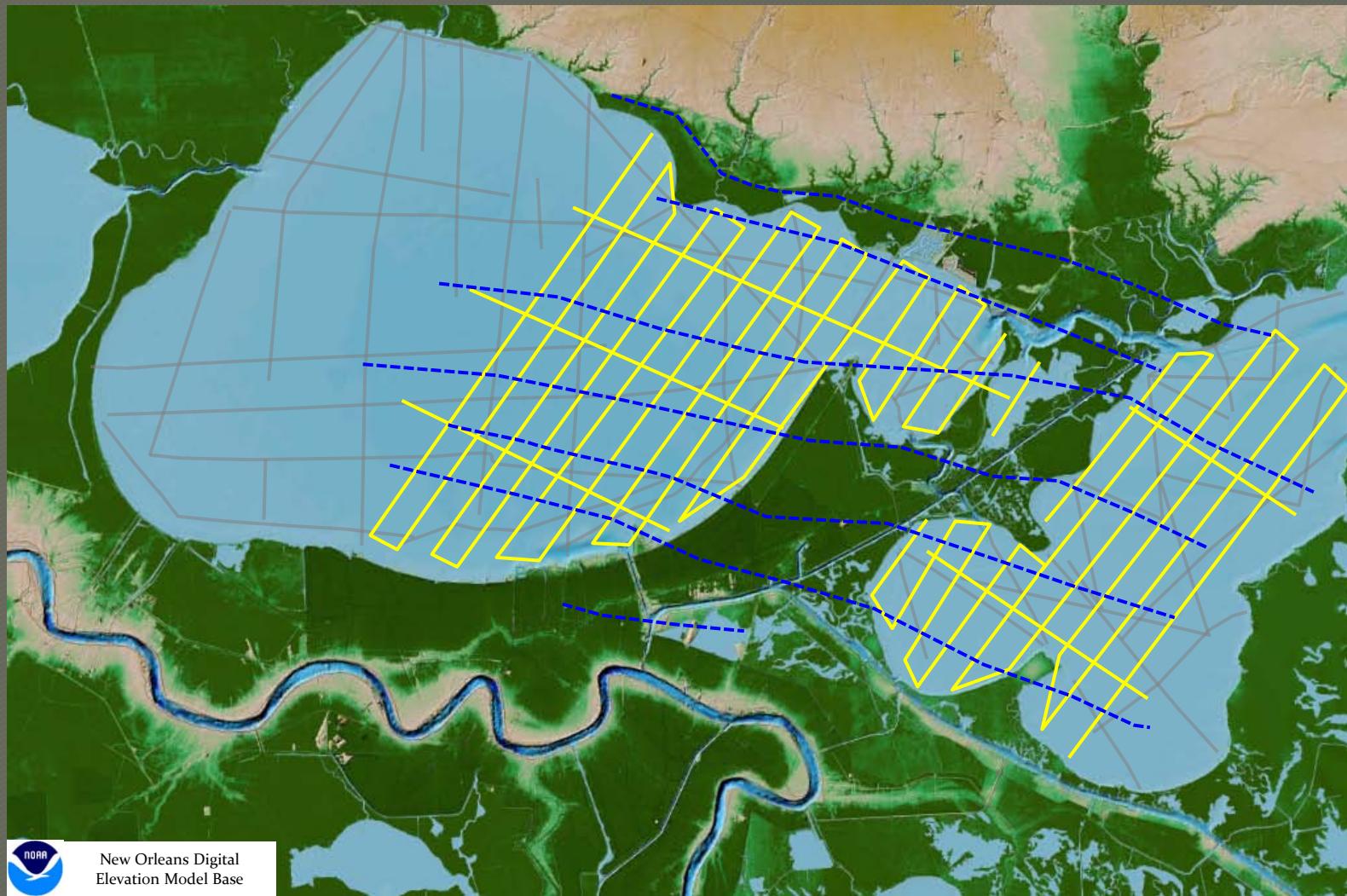
West Lake Borgne and
St. Bernard Phase I
3-D surveys – 353 sq. mi.



Lake Pontchartrain
2-D surveys – 382 line miles

Project Phase II

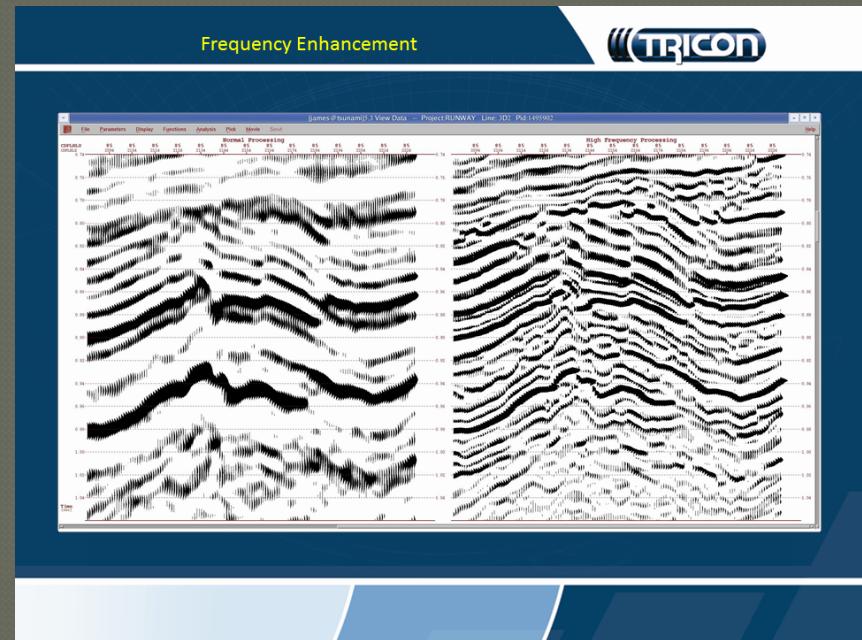
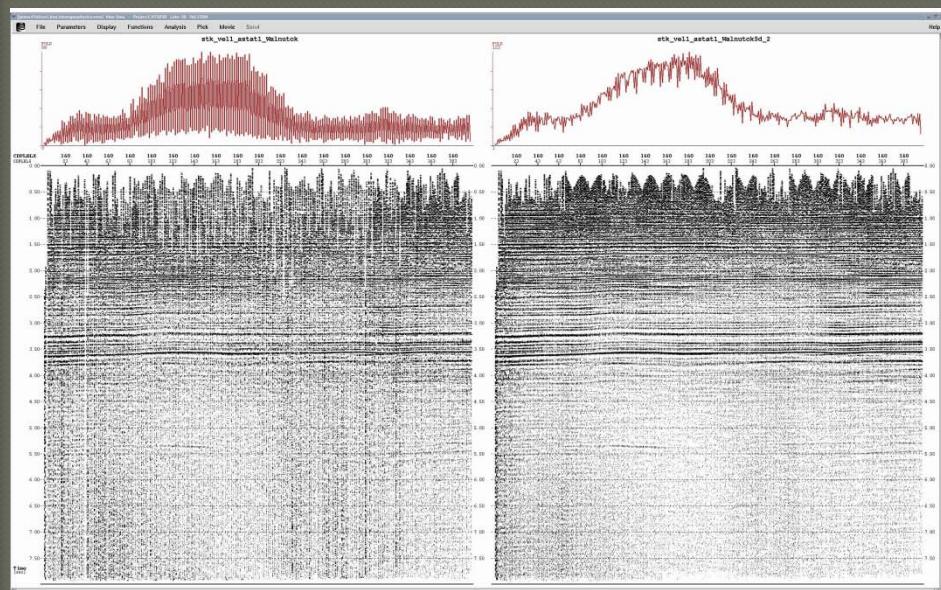
acquire hi-res seismic



New Orleans Digital
Elevation Model Base

Project Phase III

apply industry imaging technology



Project Phase IV

measure subsidence on the land surface

THE LENS
FOCUSED ON NEW ORLEANS AND THE GULF COAST

Sinking levee shows difficulty of protecting New Orleans from flooding

By Bob Marshall, Staff writer February 17, 2014 2:29pm 13 Comments

[Tweet](#) [PRINT](#)

What's more worrisome?

- A. The Army Corps of Engineers is repairing a newly-built levee that has subsided as much as six inches — the second such repair in a year and just as the state is about to take ownership of the \$14.5-billion system.
- B. No one with the regional Flood Protection Authority was surprised. In fact, they've been expecting this news.

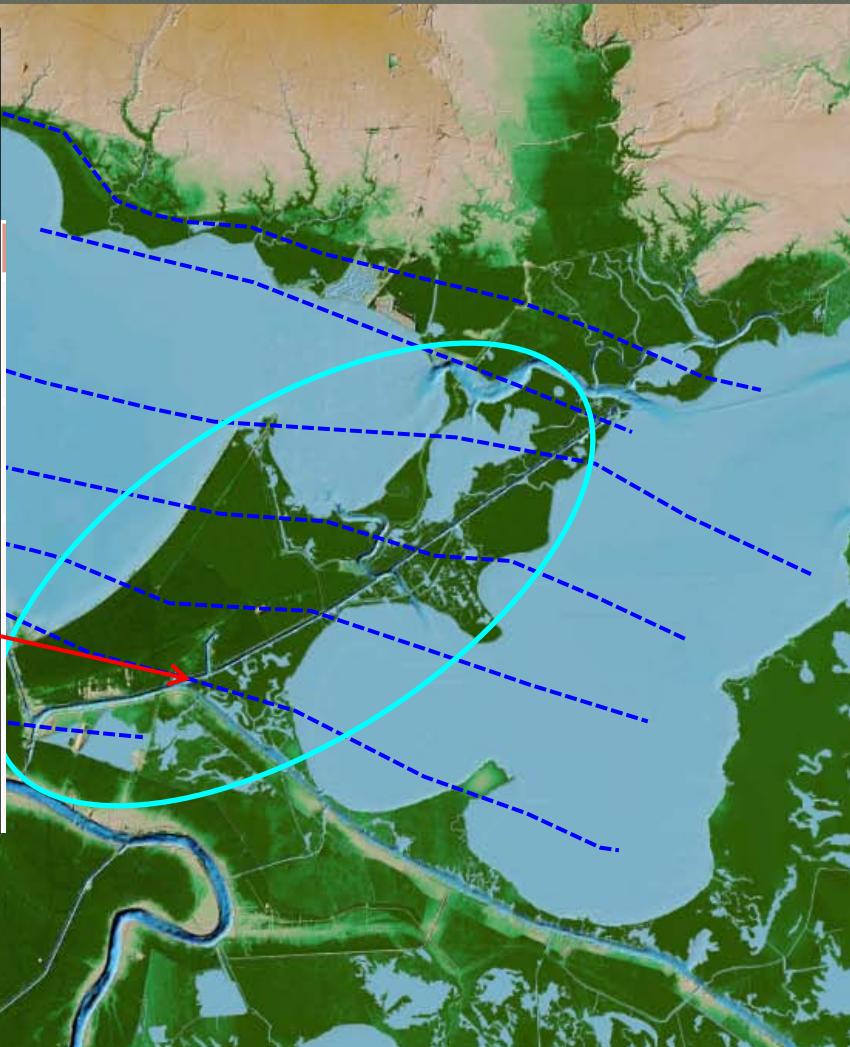
Welcome to life on a starving, sinking delta – in the middle of Hurricane Alley.

Officials recently discovered that a 1.1-mile long stretch of the levee along the Gulf Intracoastal Waterway had sunk 3 to 6 inches below its design height of 25 to 27.5 feet. It will cost about \$1 million to repair, according to the Corps of Engineers.

U.S. Army Corps of Engineers

Shown here during construction, this section of levee in the new surge protection system was recently discovered to be below design height by as much as 6 inches. The U.S. Army Corps of Engineers says repairs will cost about \$1 million and could take two and a half months.

LPV-111 Feb 05, 2011



Cooperative Research Project

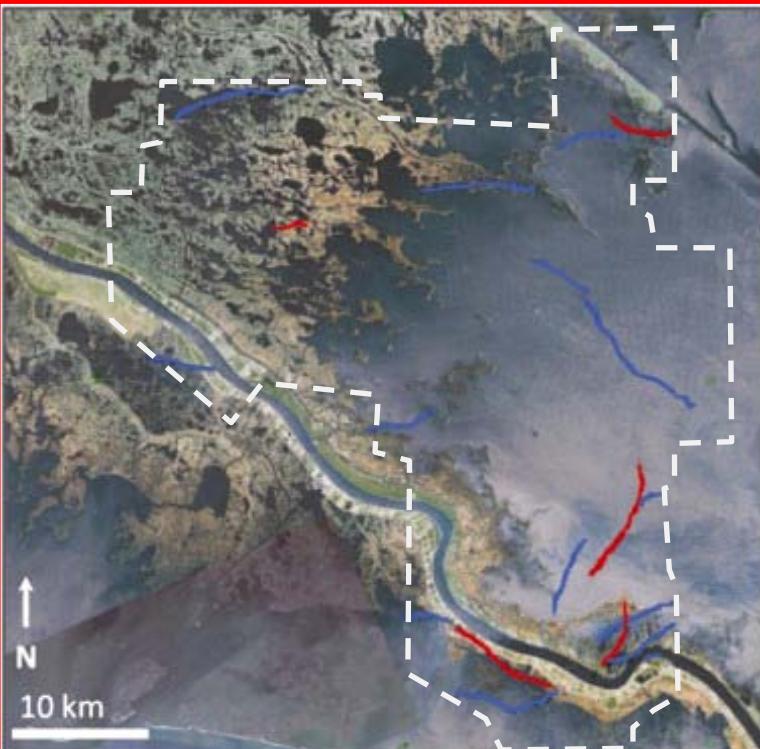


Schlumberger

LAKE PONTCHARTRAIN
BASIN FOUNDATION
SAVE OUR COAST
SAVE OUR LAKE

Land Bridge Project Phases		
I	Intrepret Seismic Data	\$150,000
II	Acquire Hires Data	\$200,000
III	Reprocess Seismic Data	\$350,000
IV	Measure Subsidence on Land	\$100,000
		\$800,000

- 1932–56 land loss²
- 1956–73 land loss^{2,4}
- 1973–75 land loss^{2,4}
- 1975–77 land loss^{2,4}
- 1977–85 land loss^{2,4}
- 1985–88 land loss²
- 1988–90 land loss²
- 1990–95 land loss²
- 1995–98 land loss²
- 1998–99 land loss²
- 1999–2002 land loss²
- 2002–4 land loss²
- 2004–6 land loss²
- 2006–8 land loss²
- 2008–9 land loss^{2,3}
- 2009–10 new water²

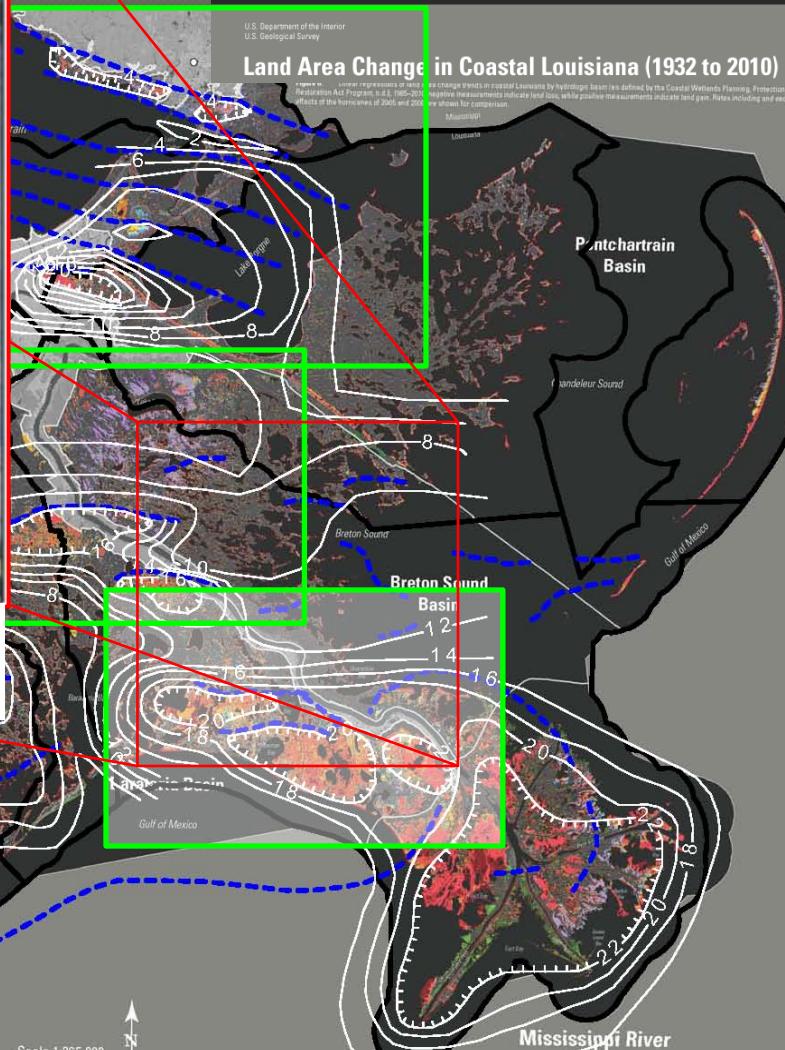


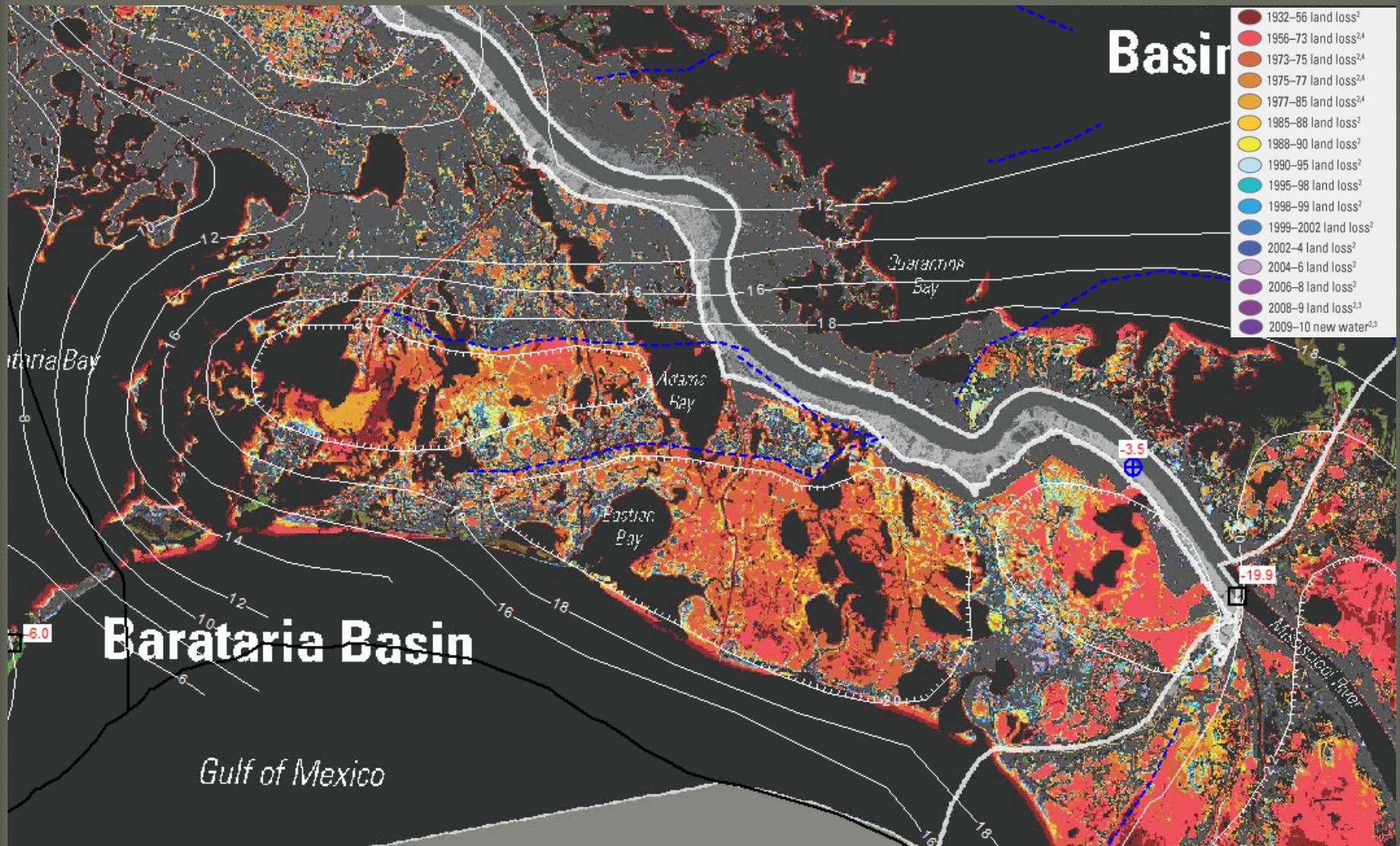
Armstrong, C. et.al., 2014, Influence of growth faults on coastal fluvial systems: Examples from the late Miocene to Recent Mississippi River Delta,

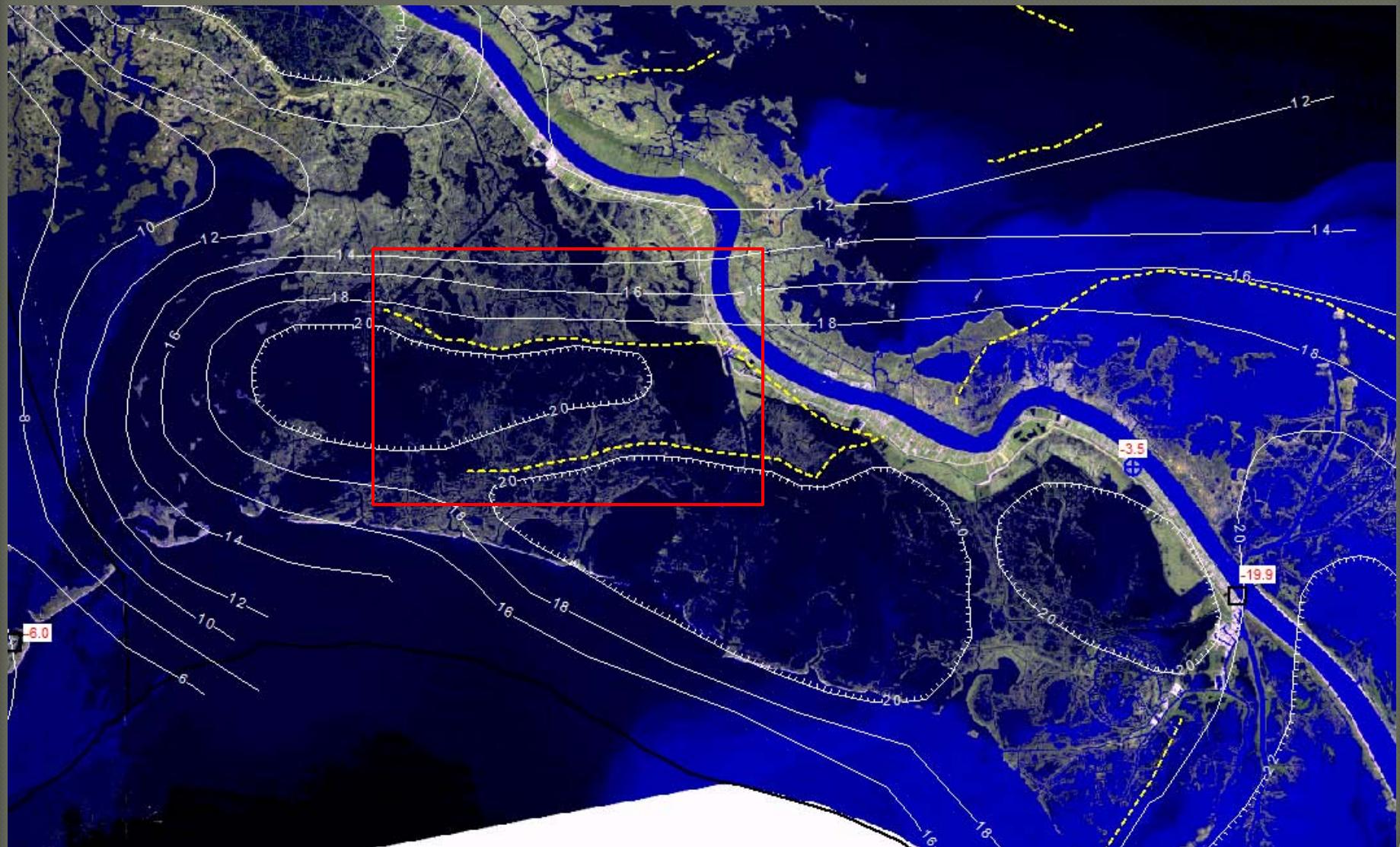
or, conversely, from open water to land may have begun that transition in an because of a secondary or composed at time period in which the paroxysm

nd other extreme storms, have annual rate of coastal land loss for example, the annual rate of coastal land loss. This is contrasted with immediate loss caused by direct losses such as from storm-driven waves, flooding, or subsidence-induced land loss following a particular storm event or later. Storm-induced storm tides

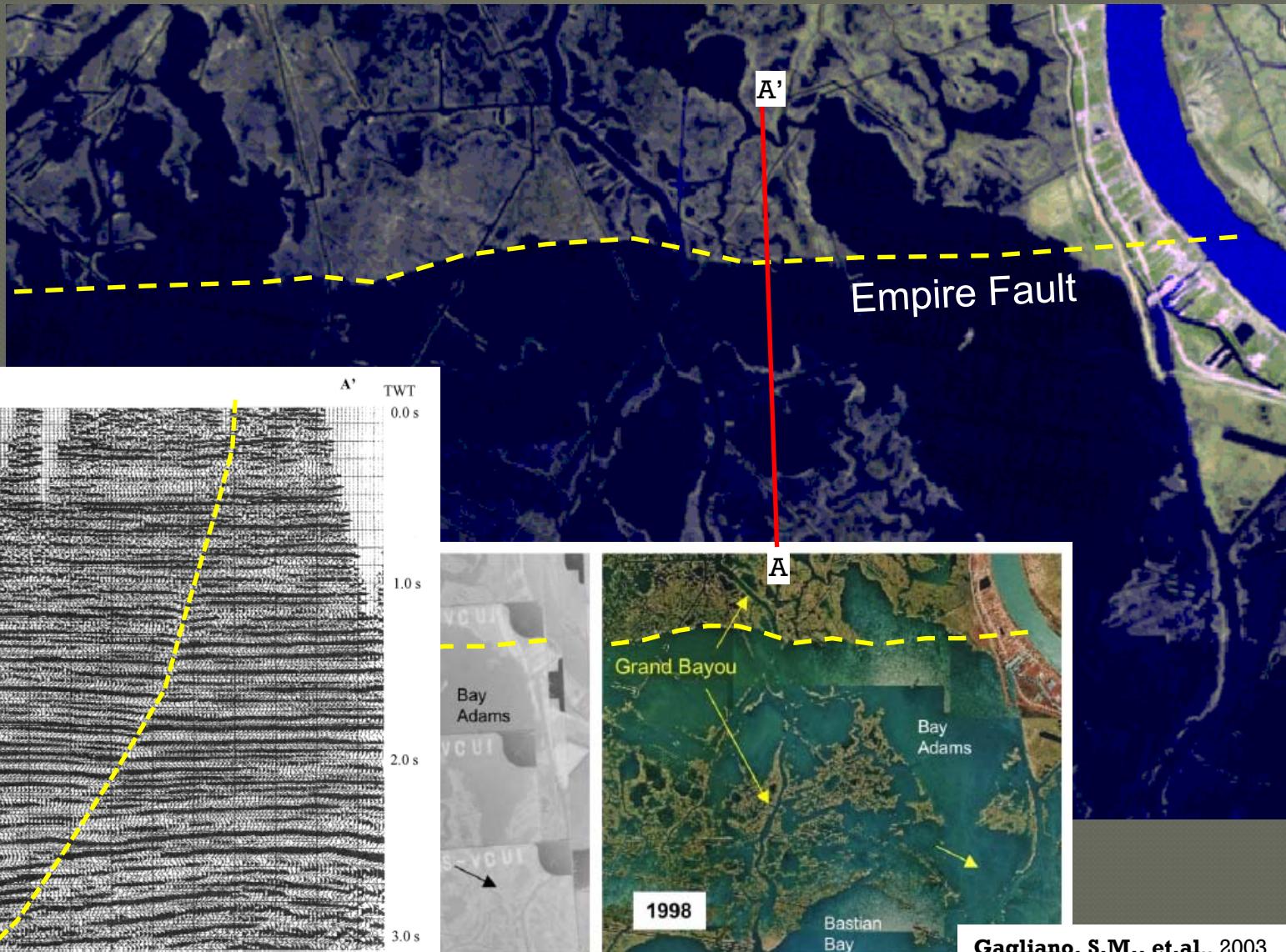
nd of coastal low had been decreasing provided by this study is allowing scientists to understand the causal mechanisms of the loss which has occurred. These understandings will provide improved information to develop tools to monitor ecosystems, forecast possible impacts, and plan protection and restoration activities. This information will facilitate development of strategies to adapt to our changing environment.





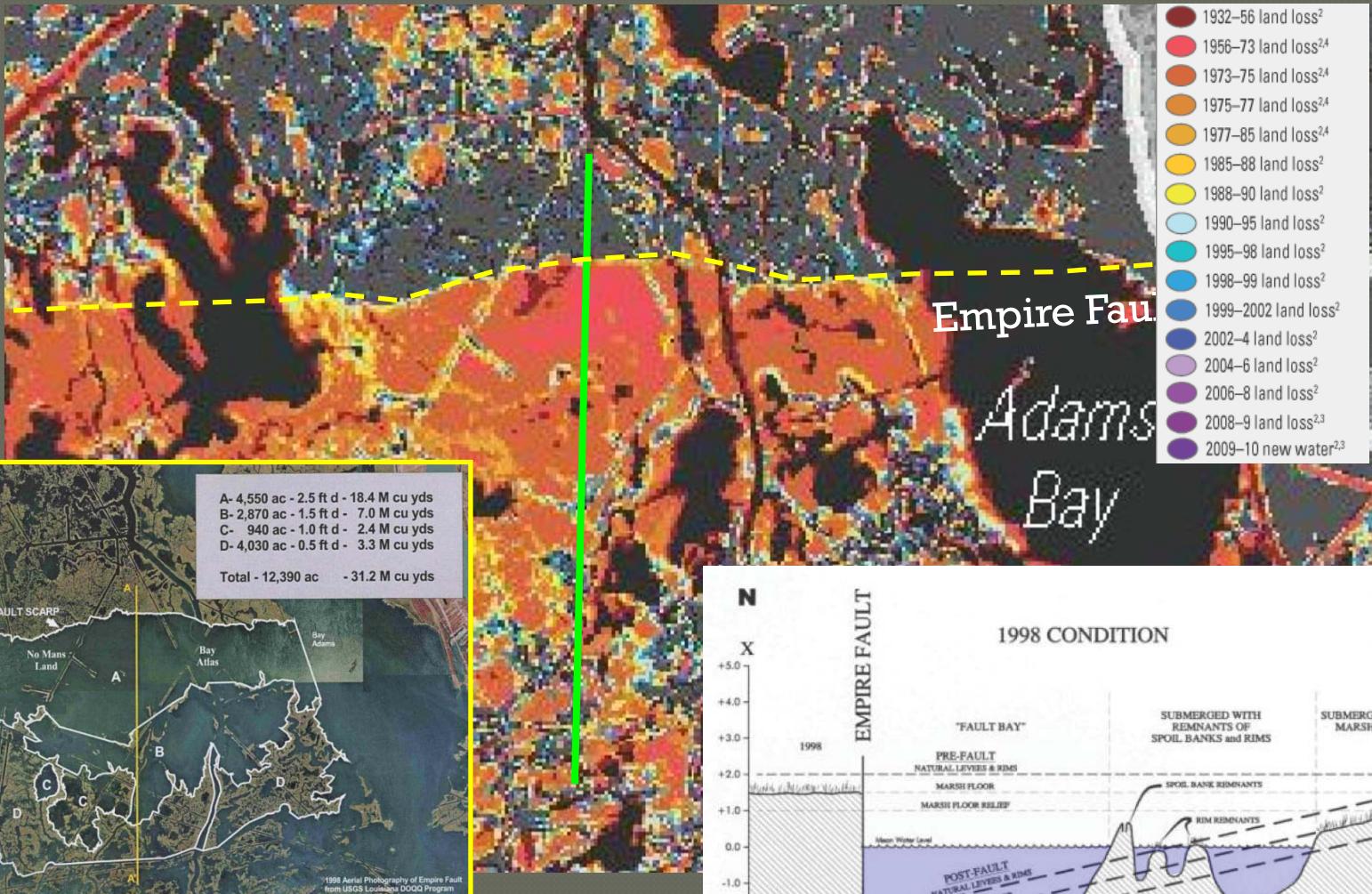


Faulting and Subsidence



Gagliano, S.M., et.al., 2003

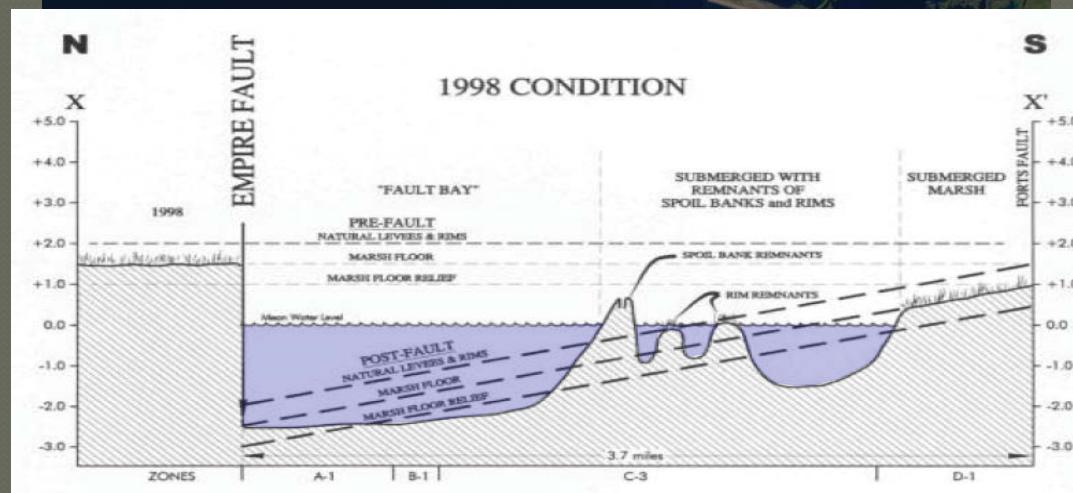
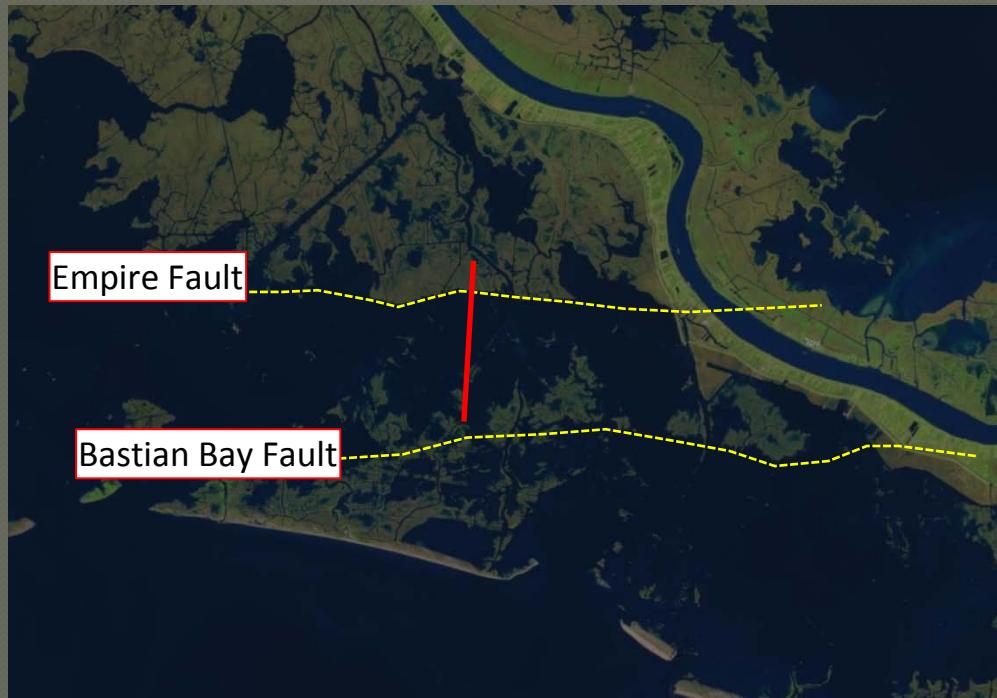
Marsh Subsidence Due to Faulting



Gagliano, S.M., et.al., 2003

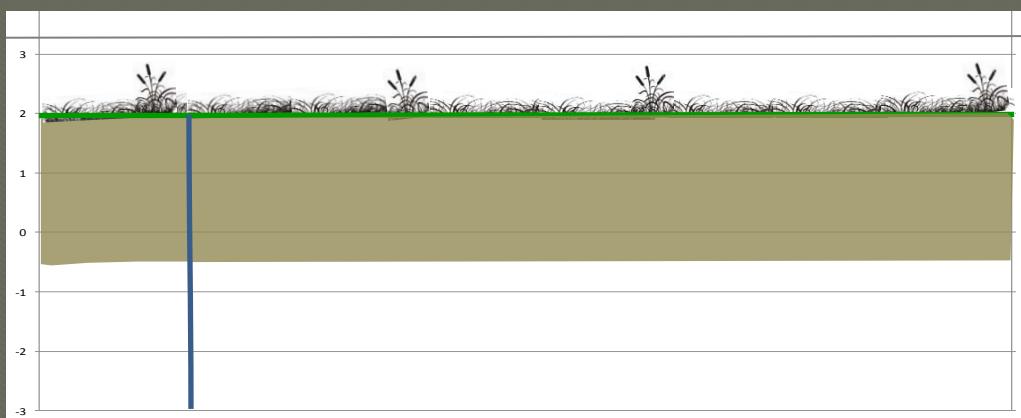
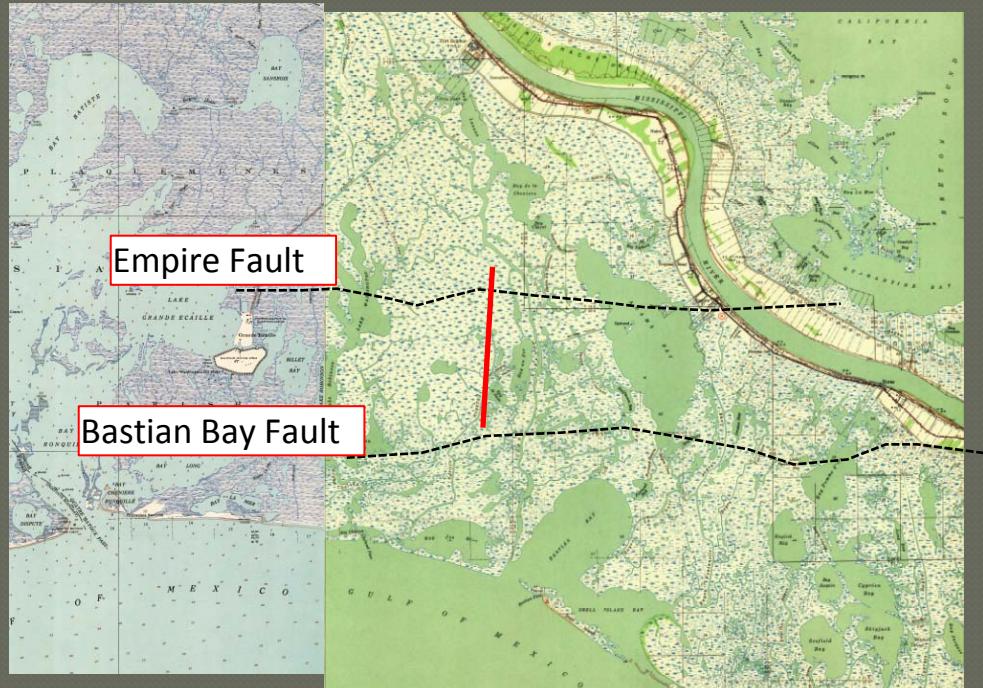
Faulting and Subsidence

2013



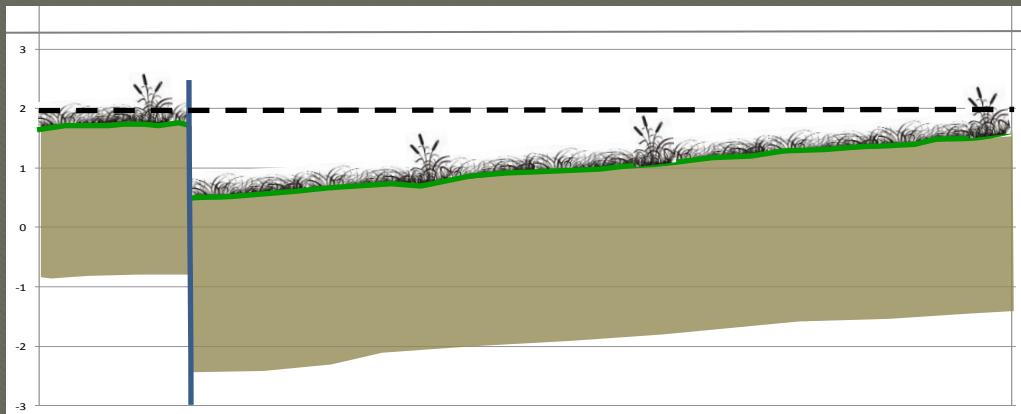
Faulting and Subsidence

1941



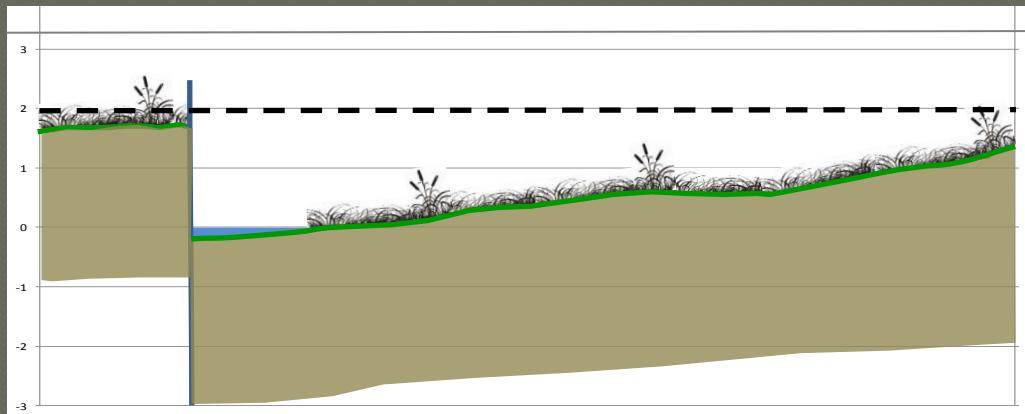
Faulting and Subsidence

1973



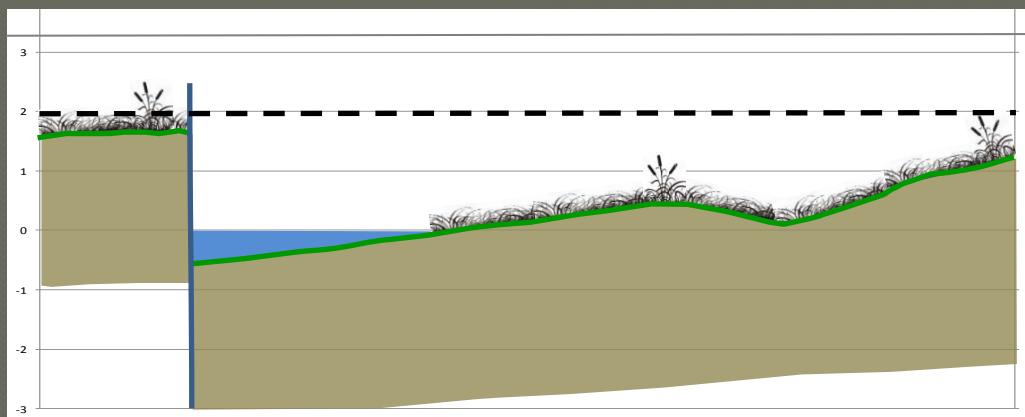
Faulting and Subsidence

1978



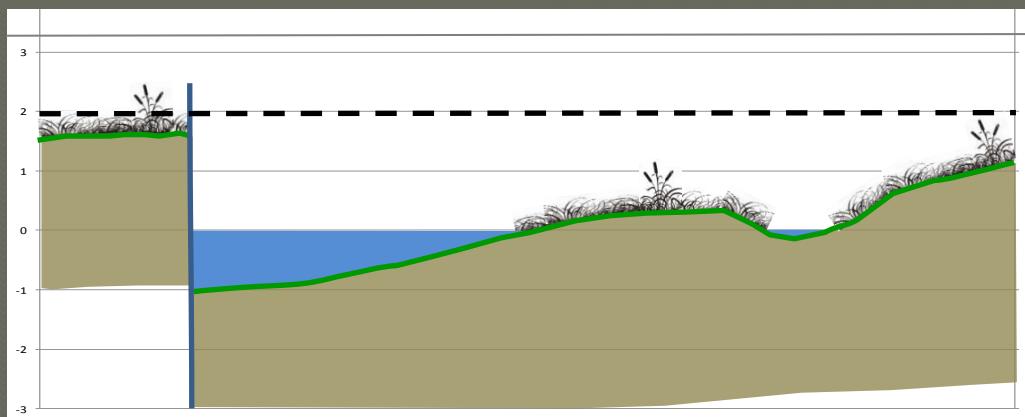
Faulting and Subsidence

1985



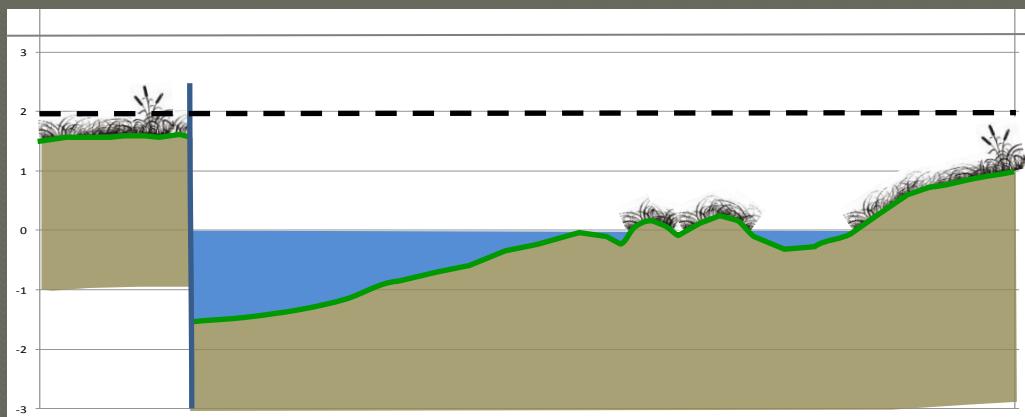
Faulting and Subsidence

1995



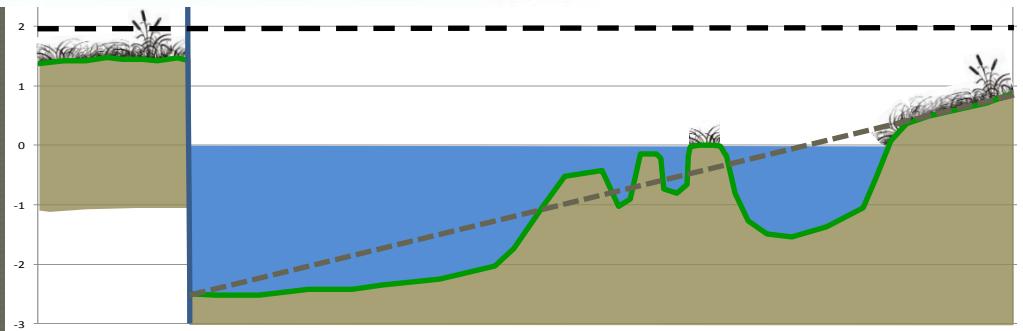
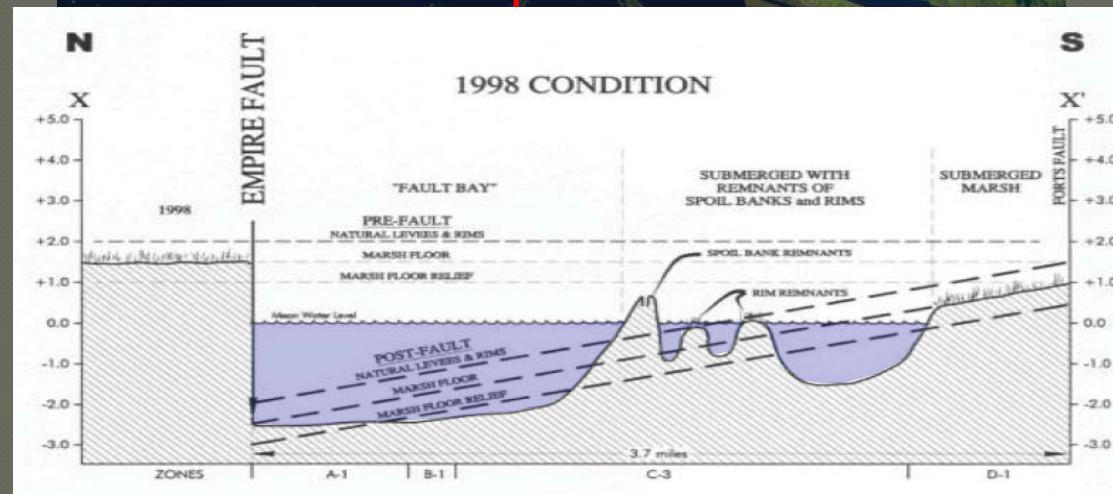
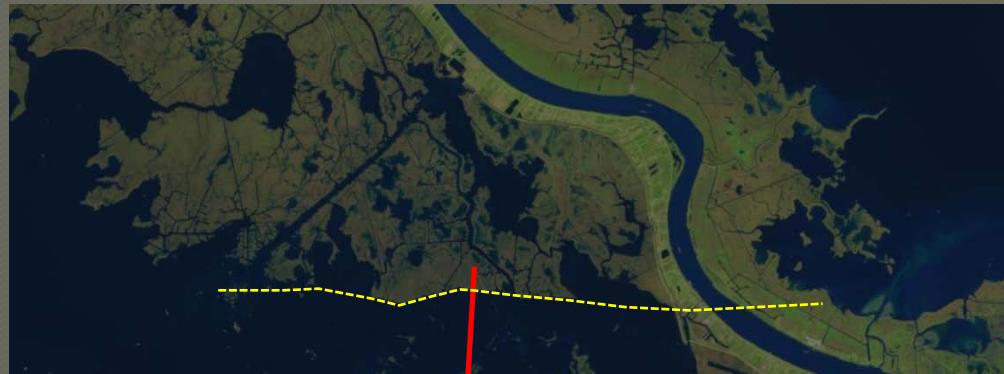
Faulting and Subsidence

1997

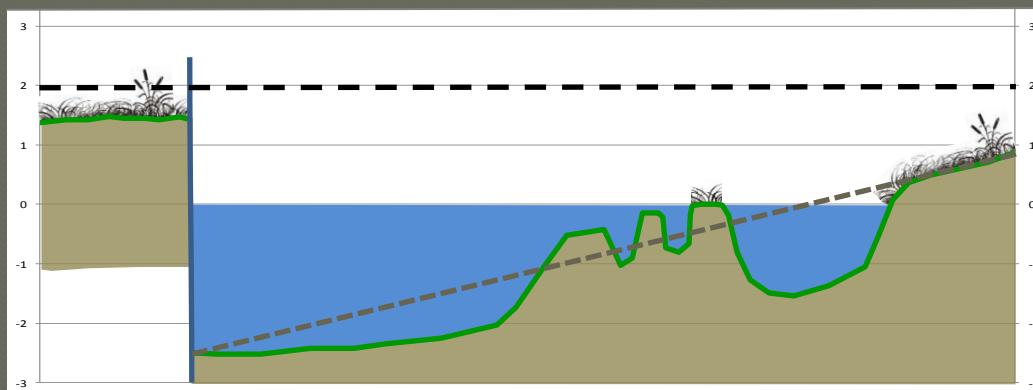
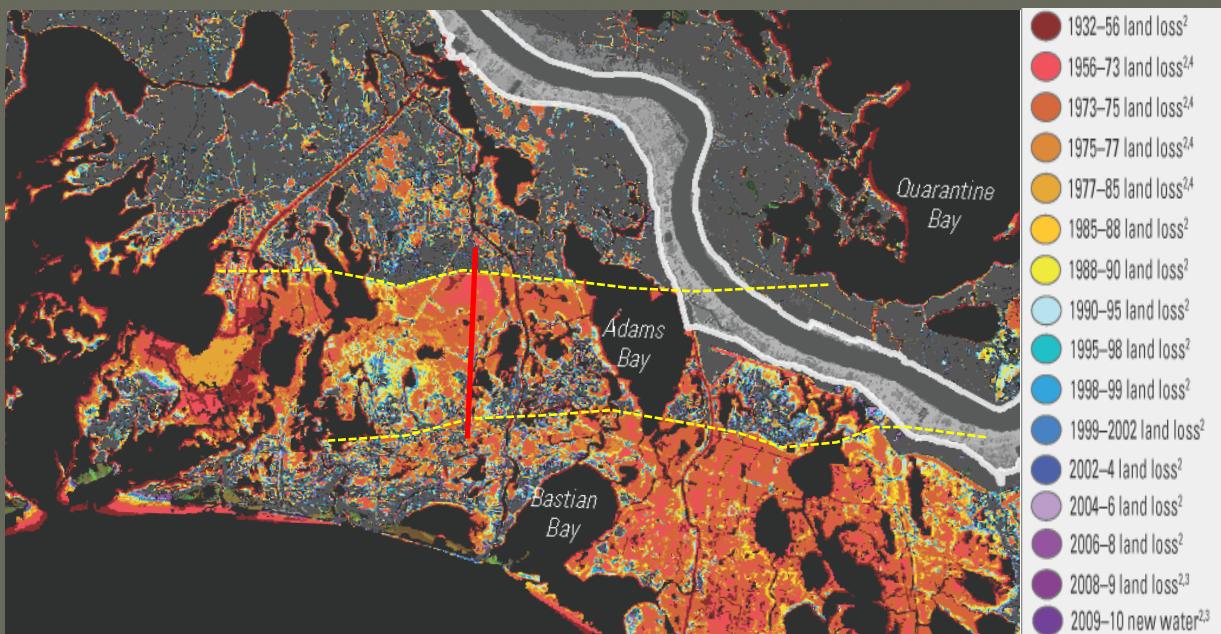


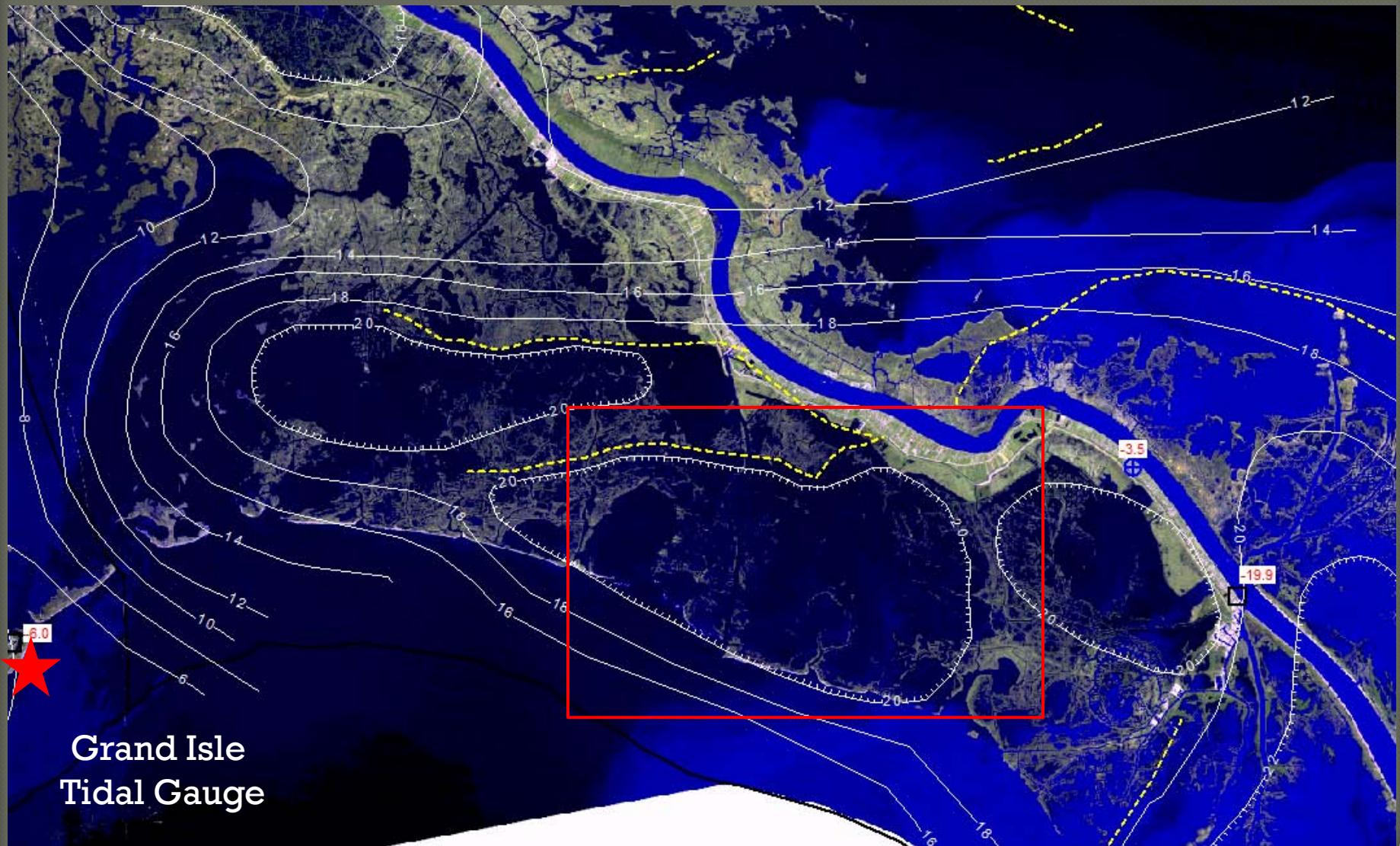
Faulting and Subsidence

2013



Faulting, Subsidence and Land Loss





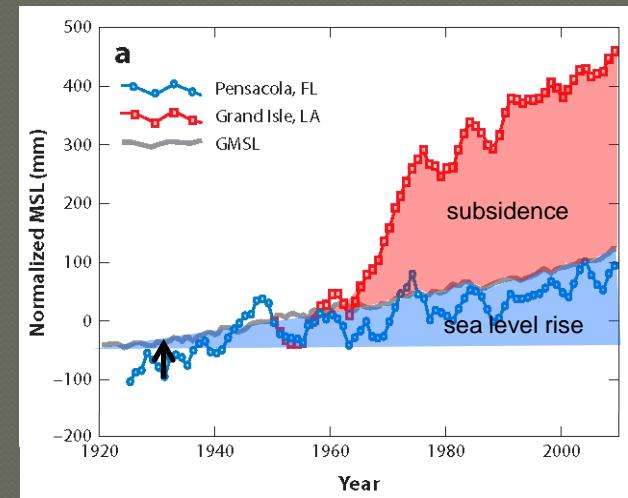
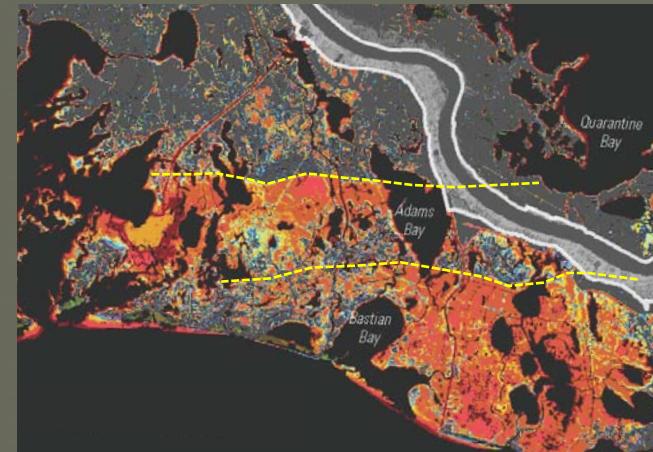
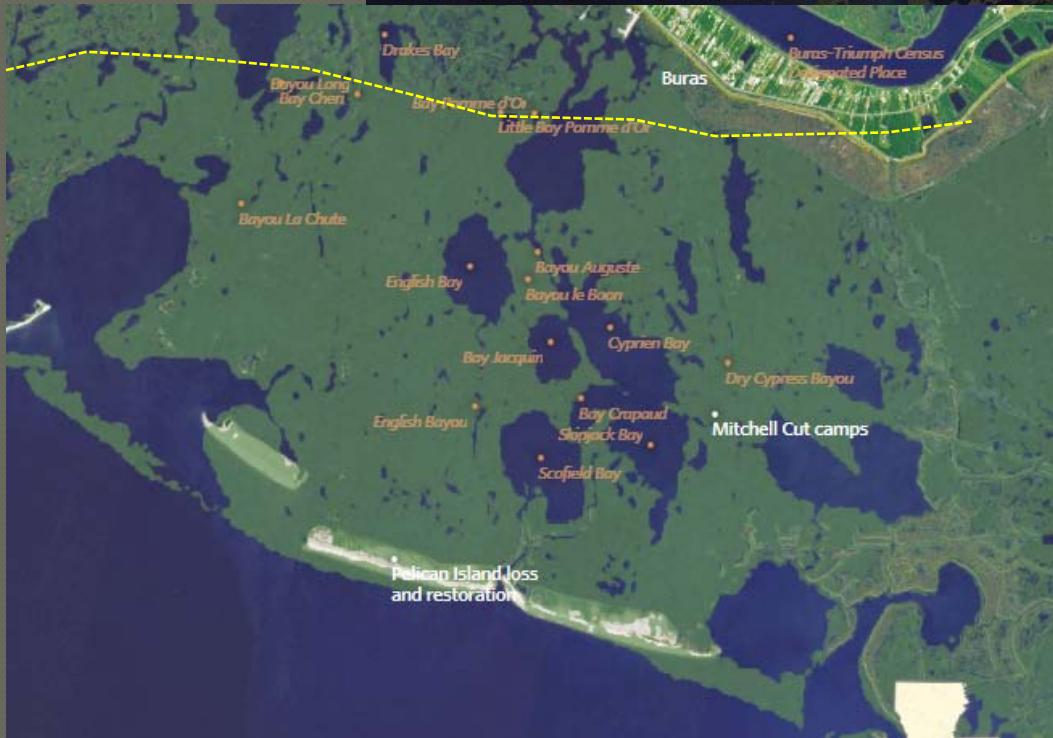
Faulting, Subsidence and Land Loss

1932

Losing Ground

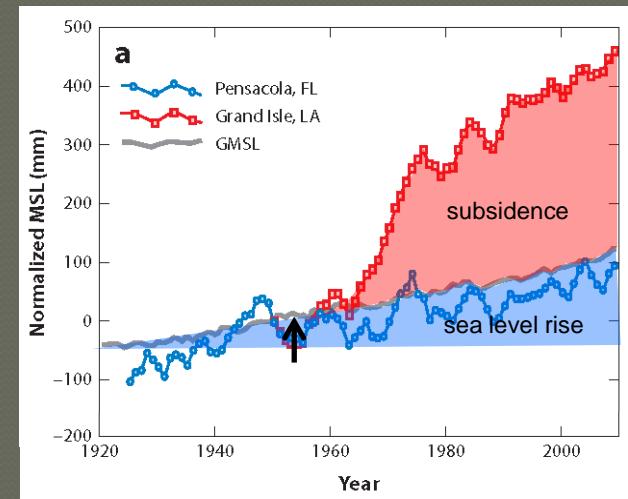
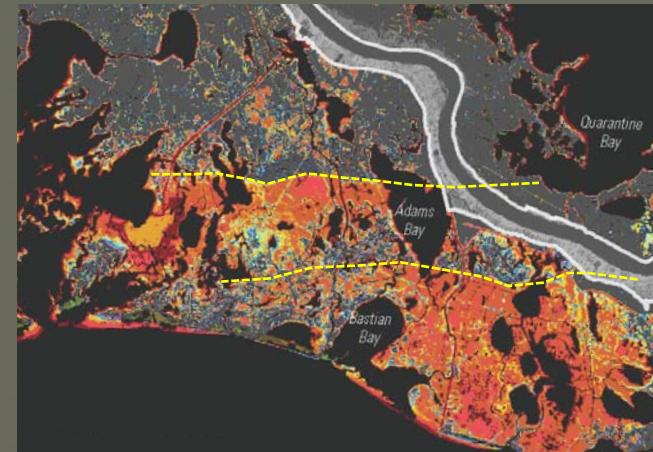
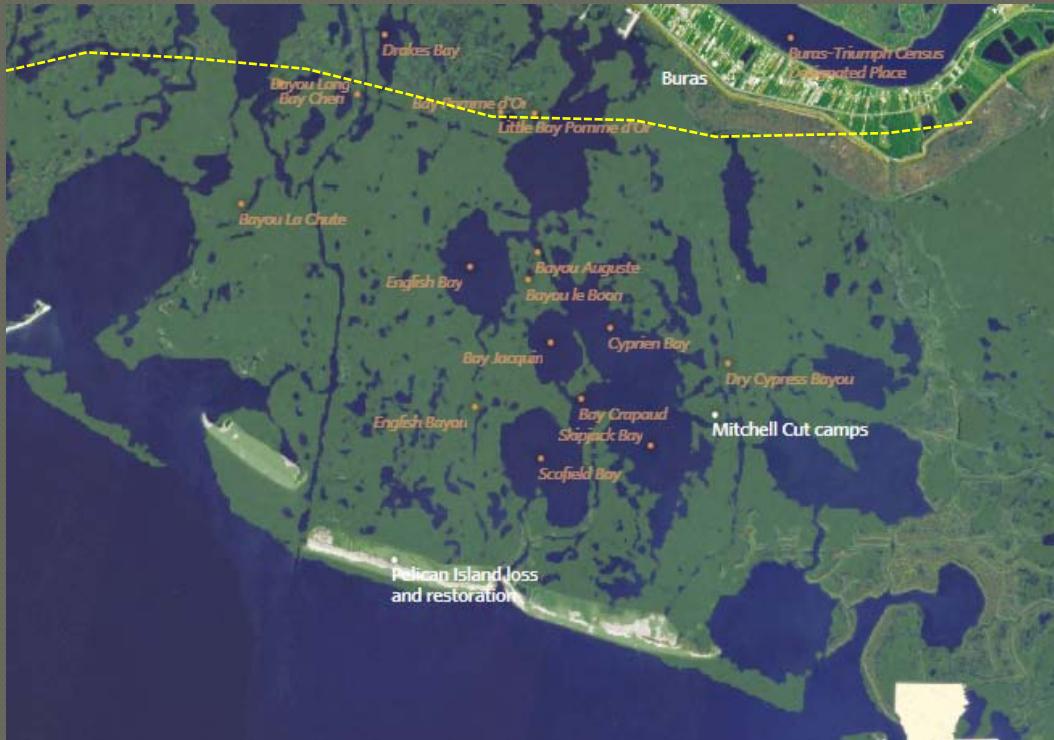
by Bob Marshall, The Lens, Brian Jacobs and Al Shaw, ProPublica, Aug. 28, 2014

In 50 years, most of southeastern Louisiana not protected by levees will be part of the Gulf of Mexico.



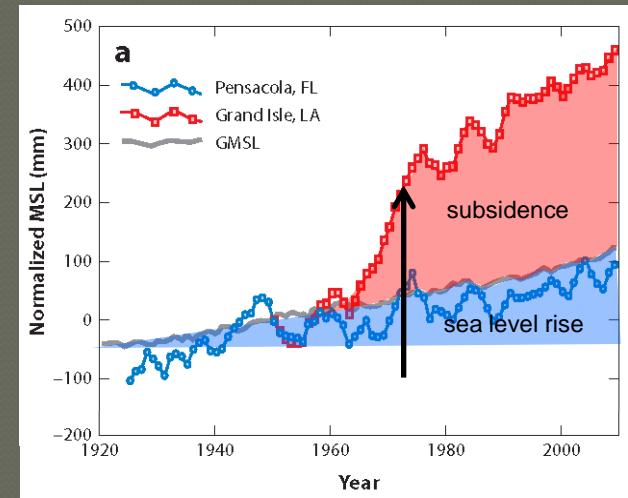
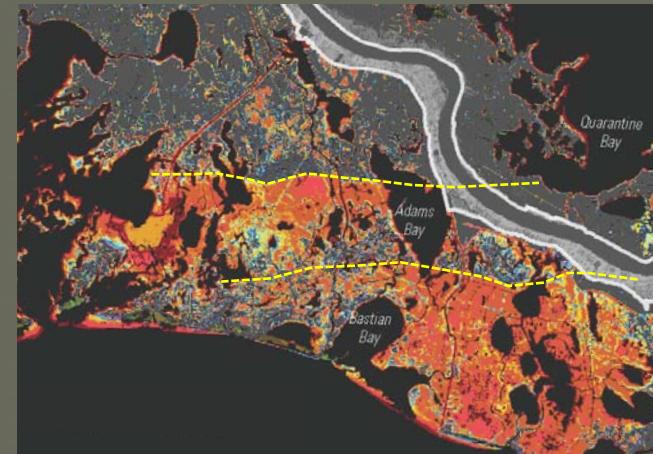
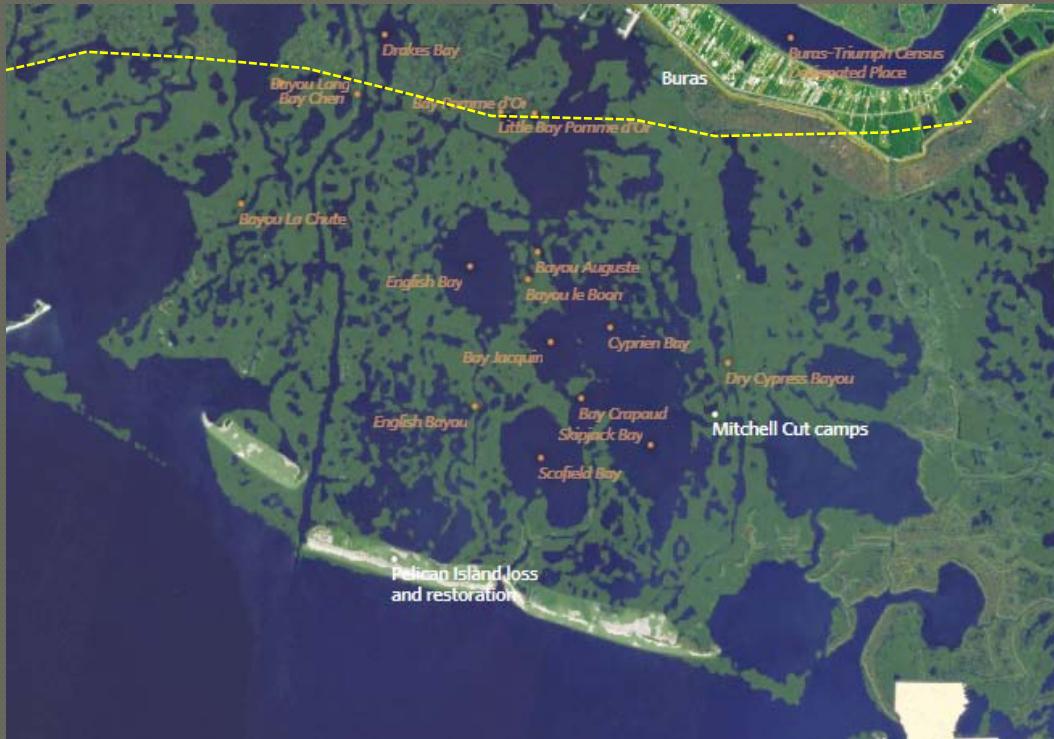
Faulting, Subsidence and Land Loss

1956



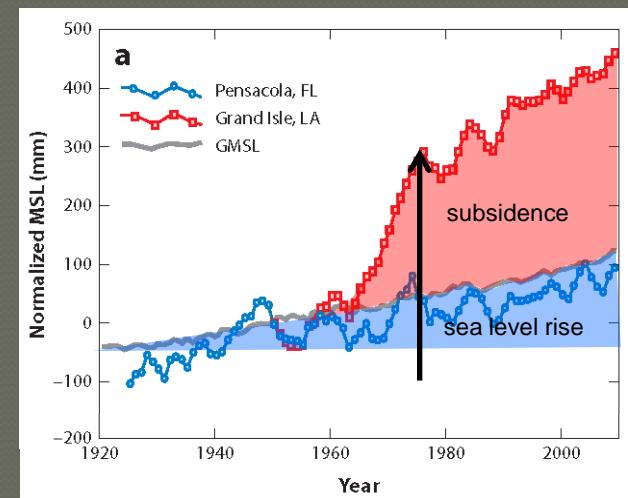
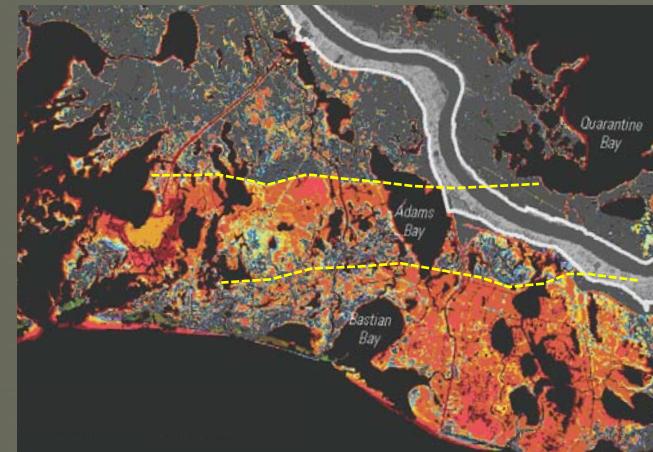
Faulting, Subsidence and Land Loss

1973



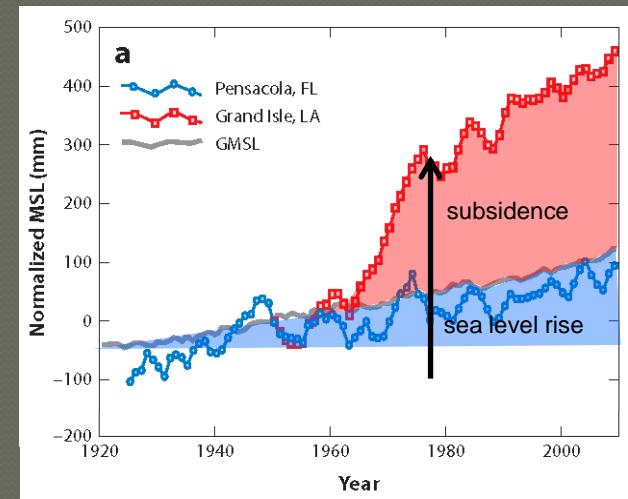
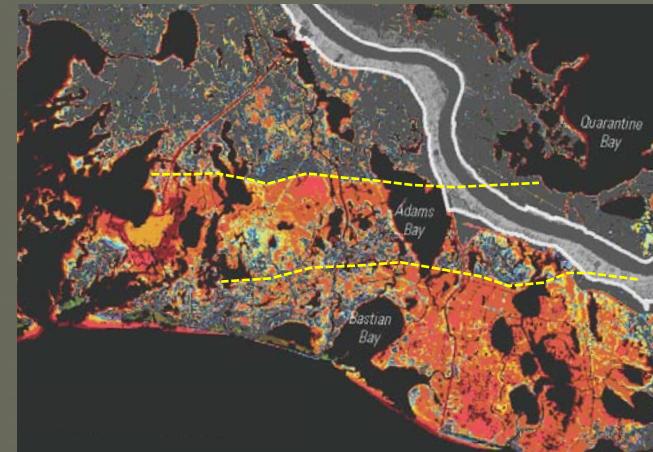
Faulting, Subsidence and Land Loss

1975



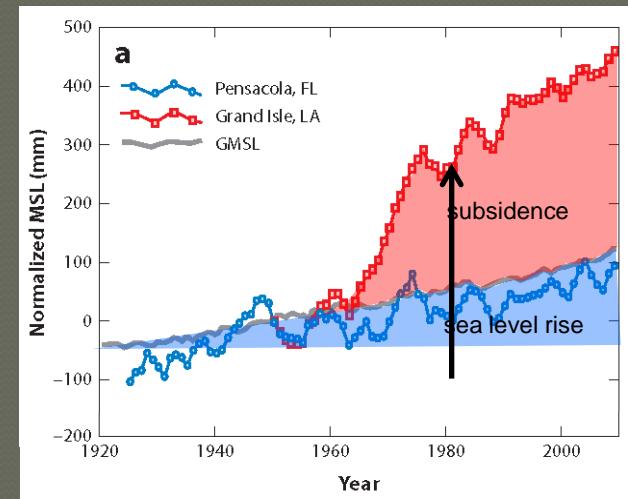
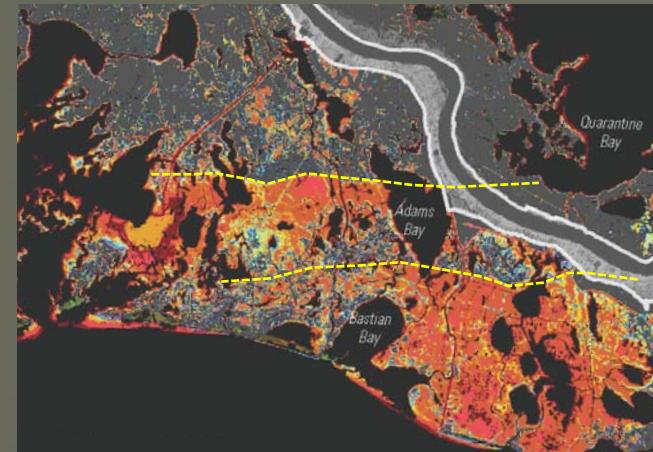
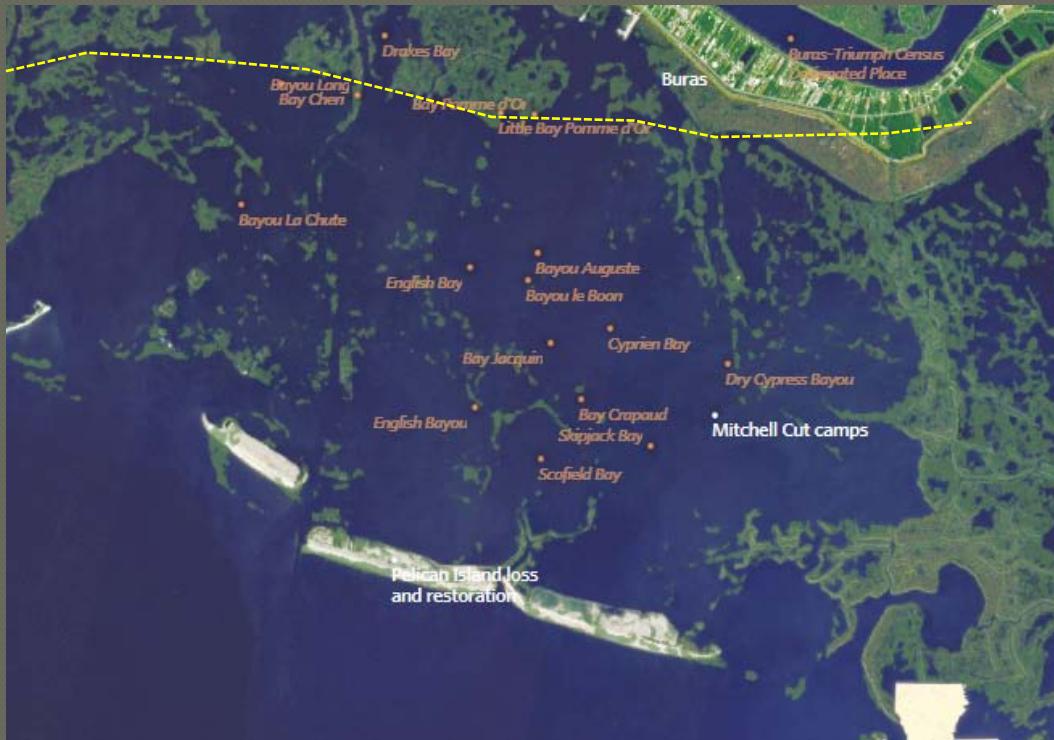
Faulting, Subsidence and Land Loss

1977



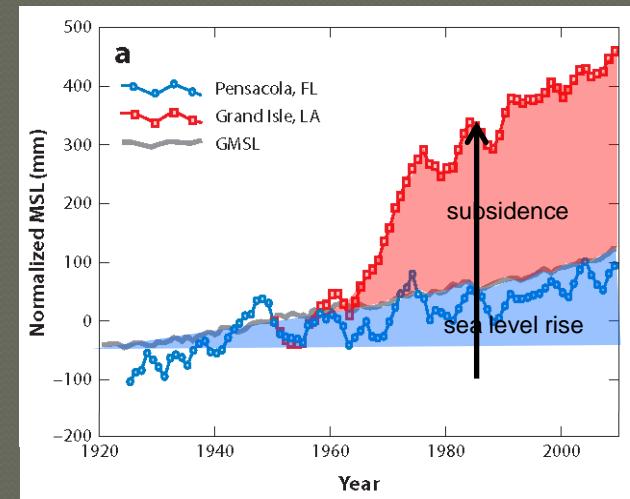
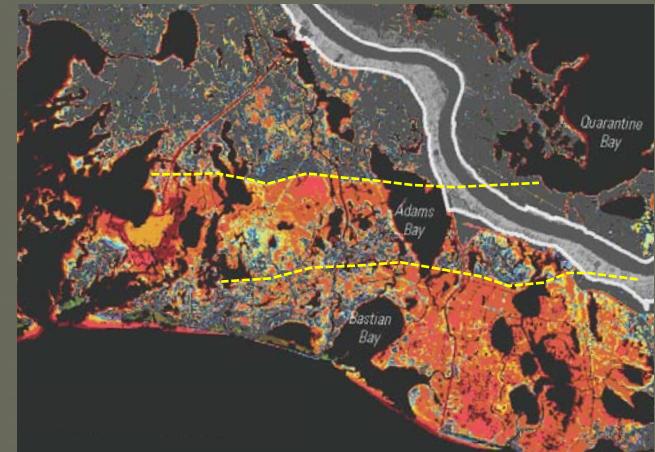
Faulting, Subsidence and Land Loss

1985



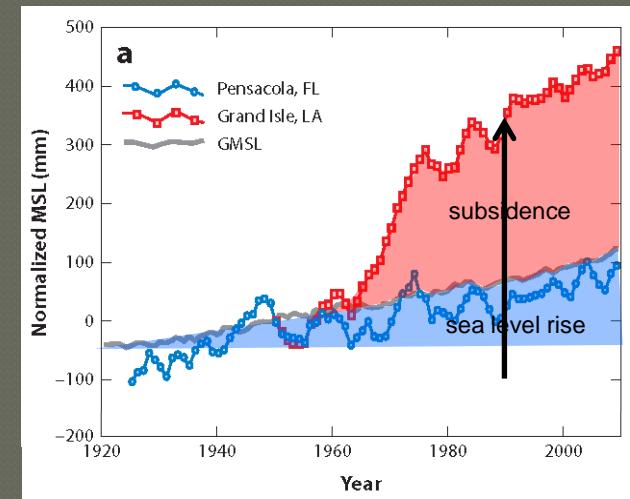
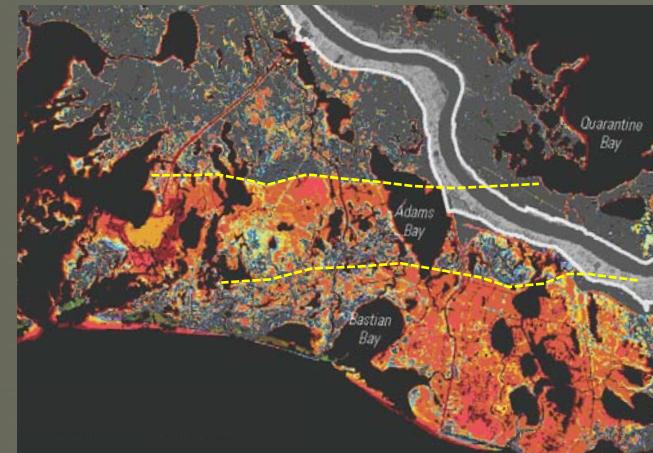
Faulting, Subsidence and Land Loss

1988



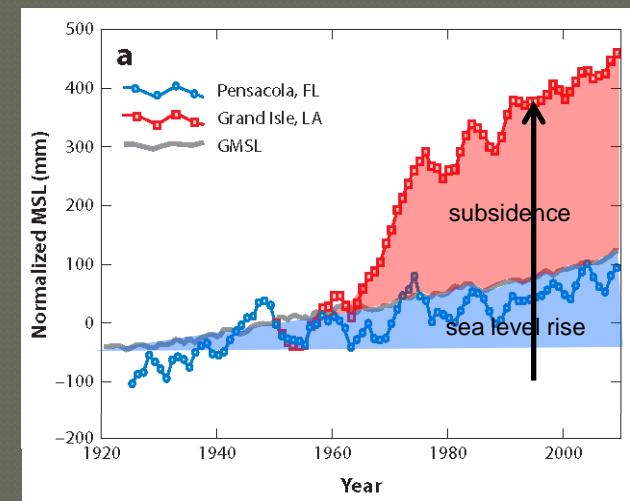
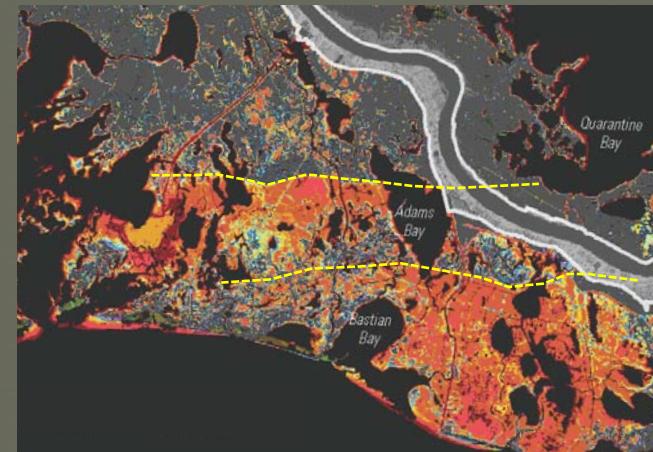
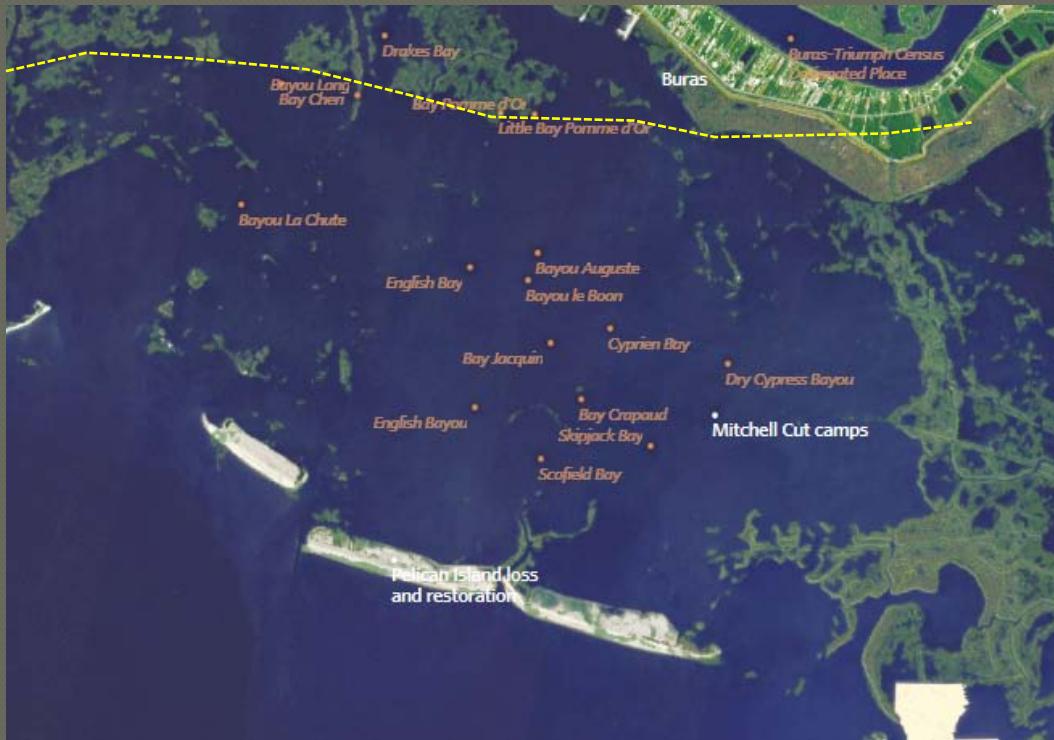
Faulting, Subsidence and Land Loss

1990



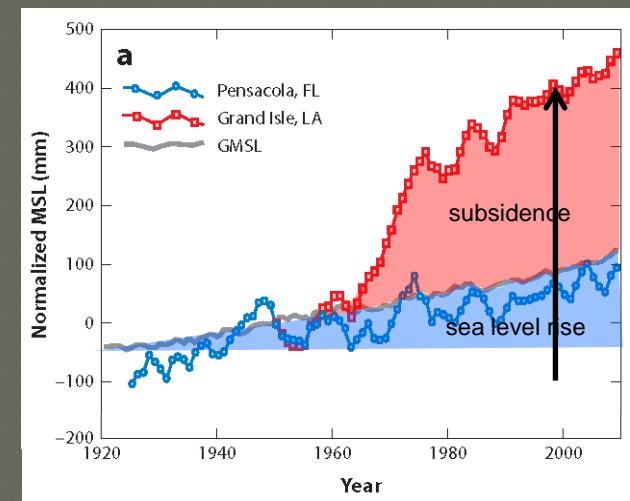
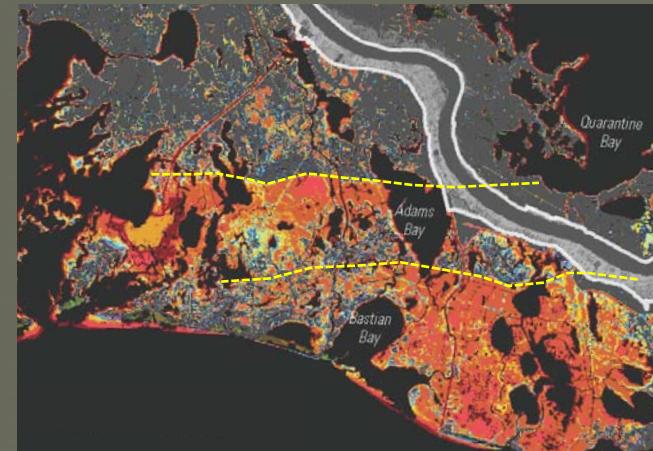
Faulting, Subsidence and Land Loss

1995



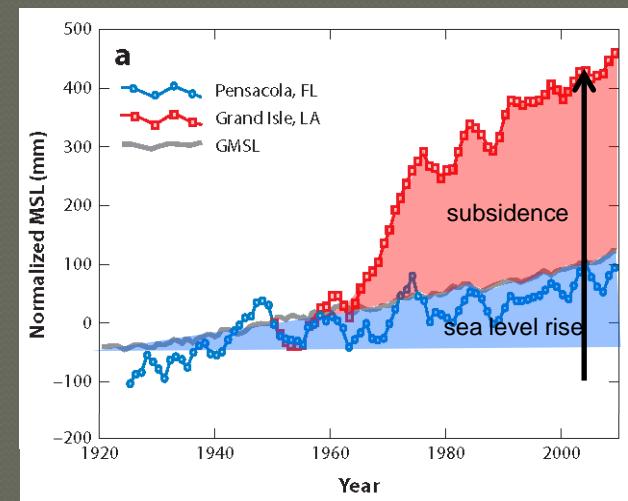
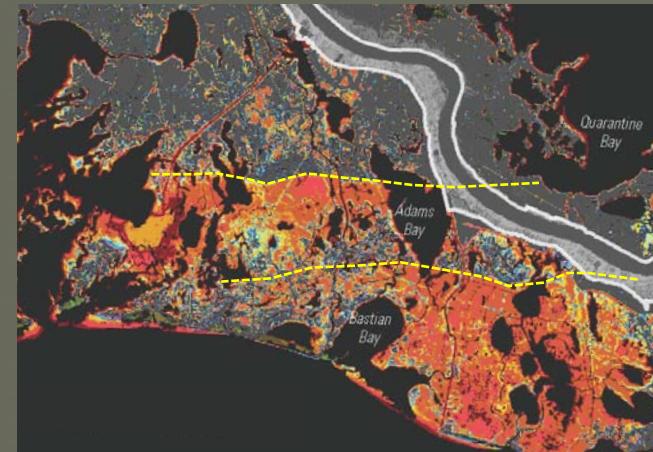
Faulting, Subsidence and Land Loss

1999



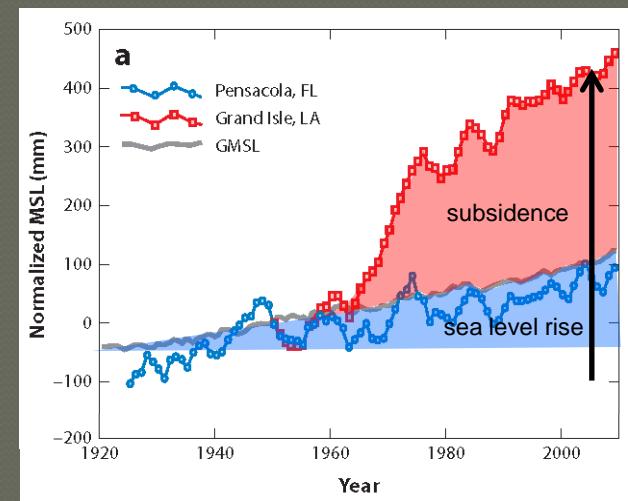
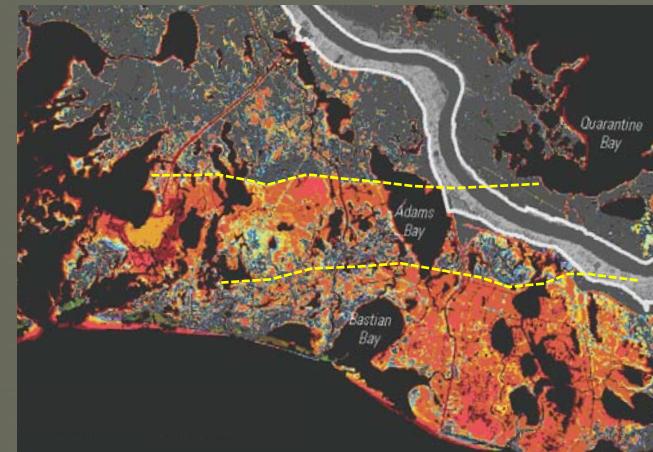
Faulting, Subsidence and Land Loss

2004



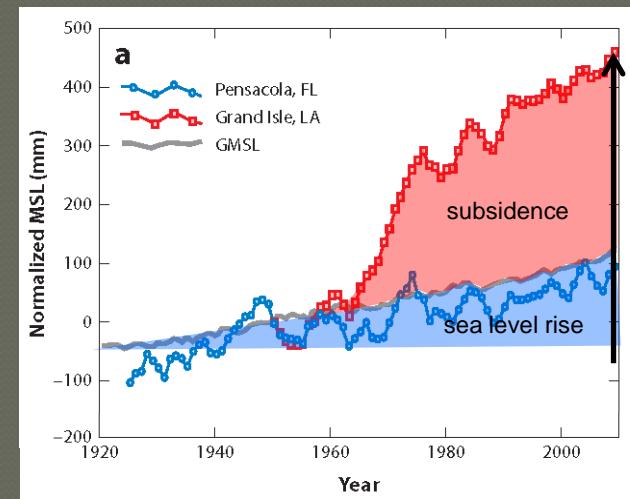
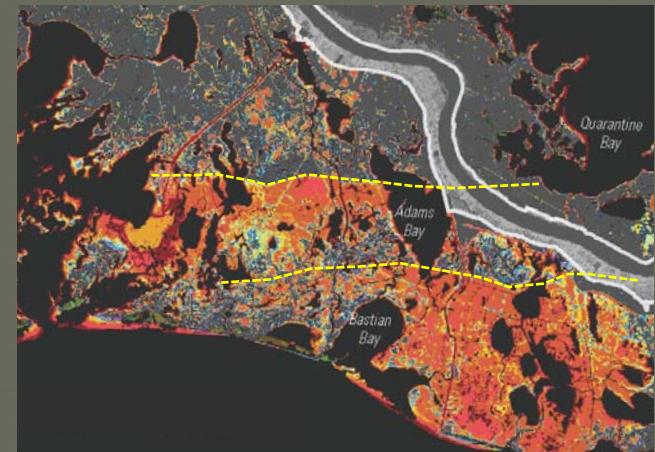
Faulting, Subsidence and Land Loss

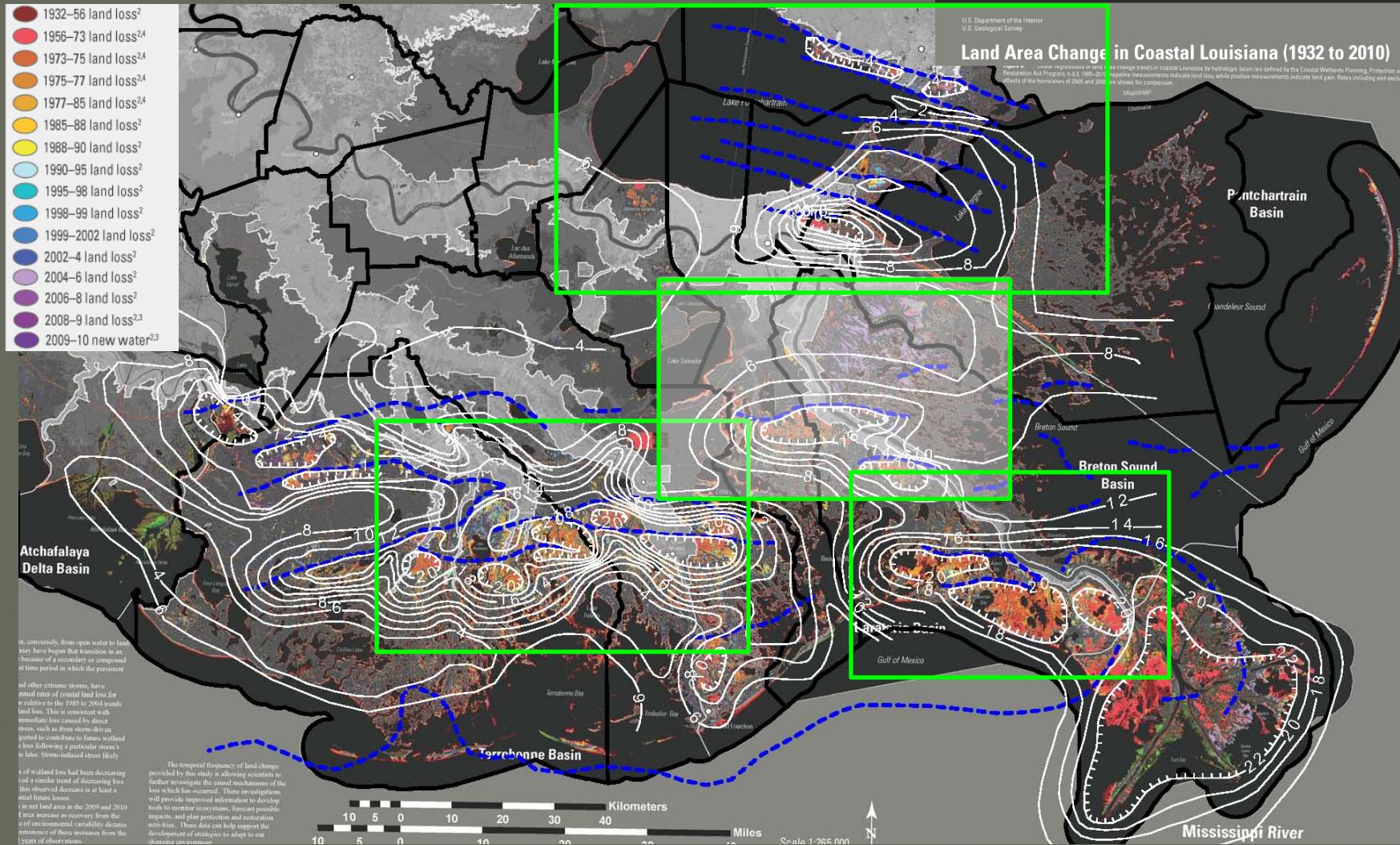
2006

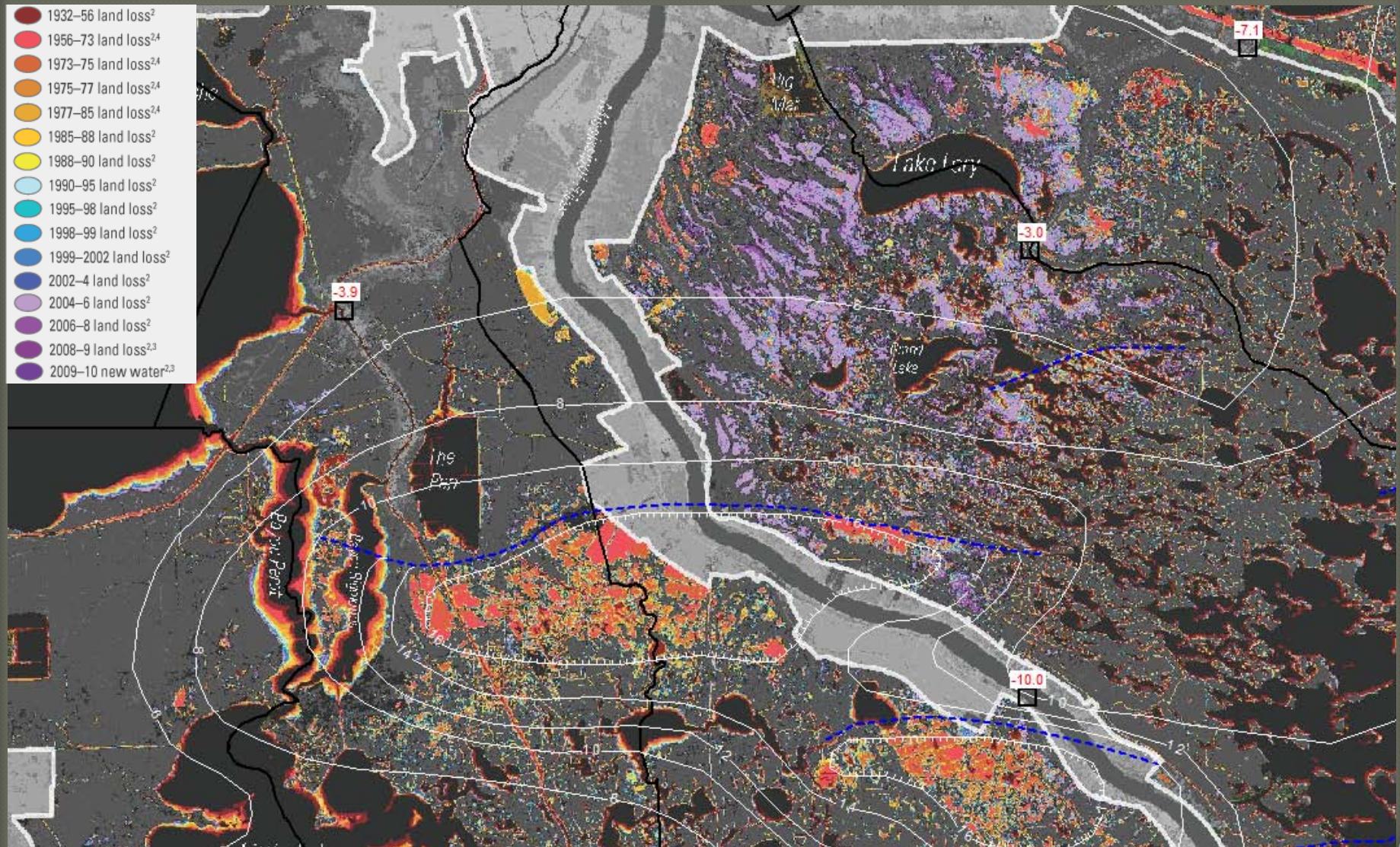


Faulting, Subsidence and Land Loss

2009









Myrtle Grove Area



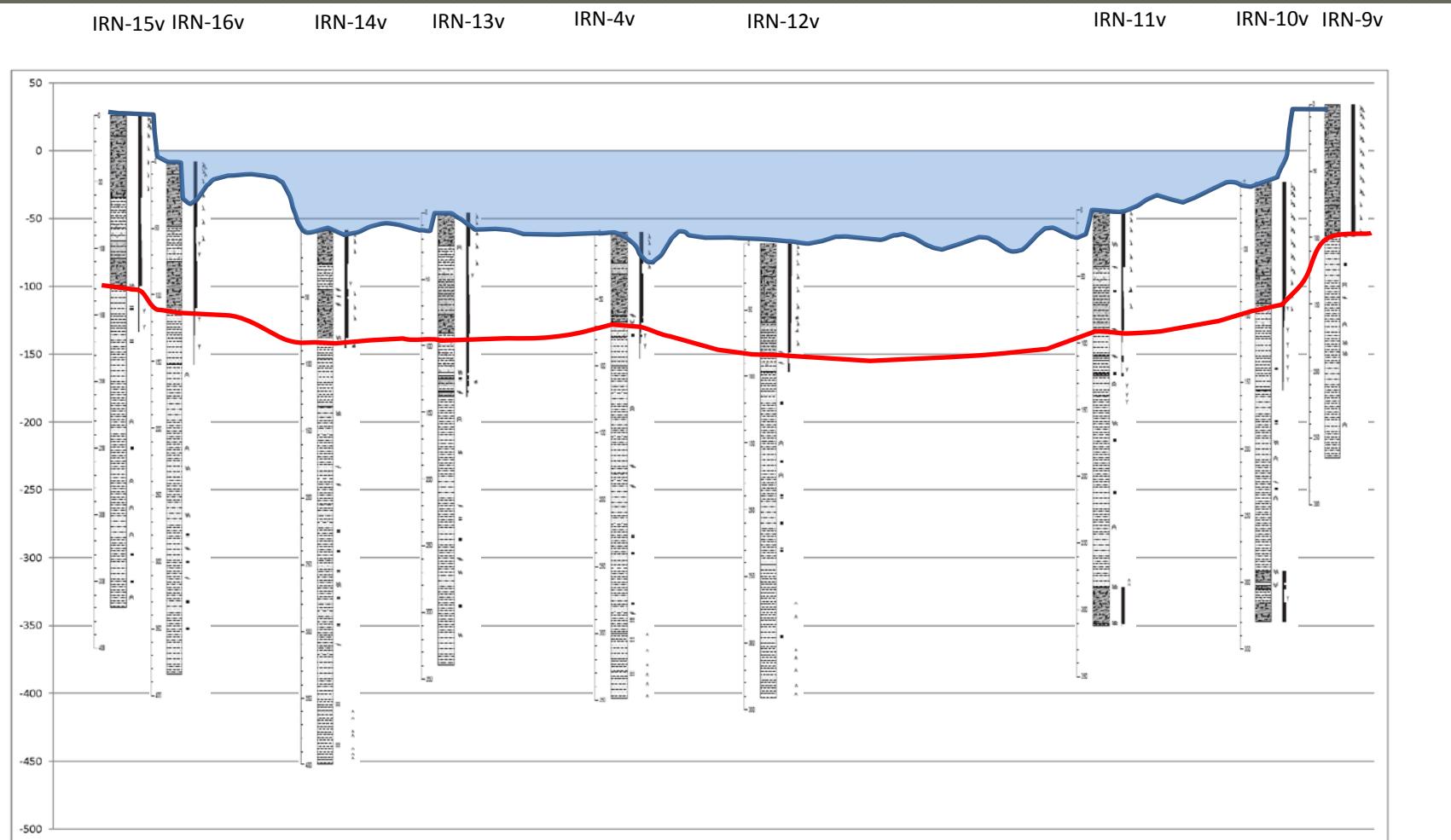
Losing Ground

by Bob Marshall, The Lens, Brian Jacobs and Al Shaw, ProPublica, Aug. 28, 2014

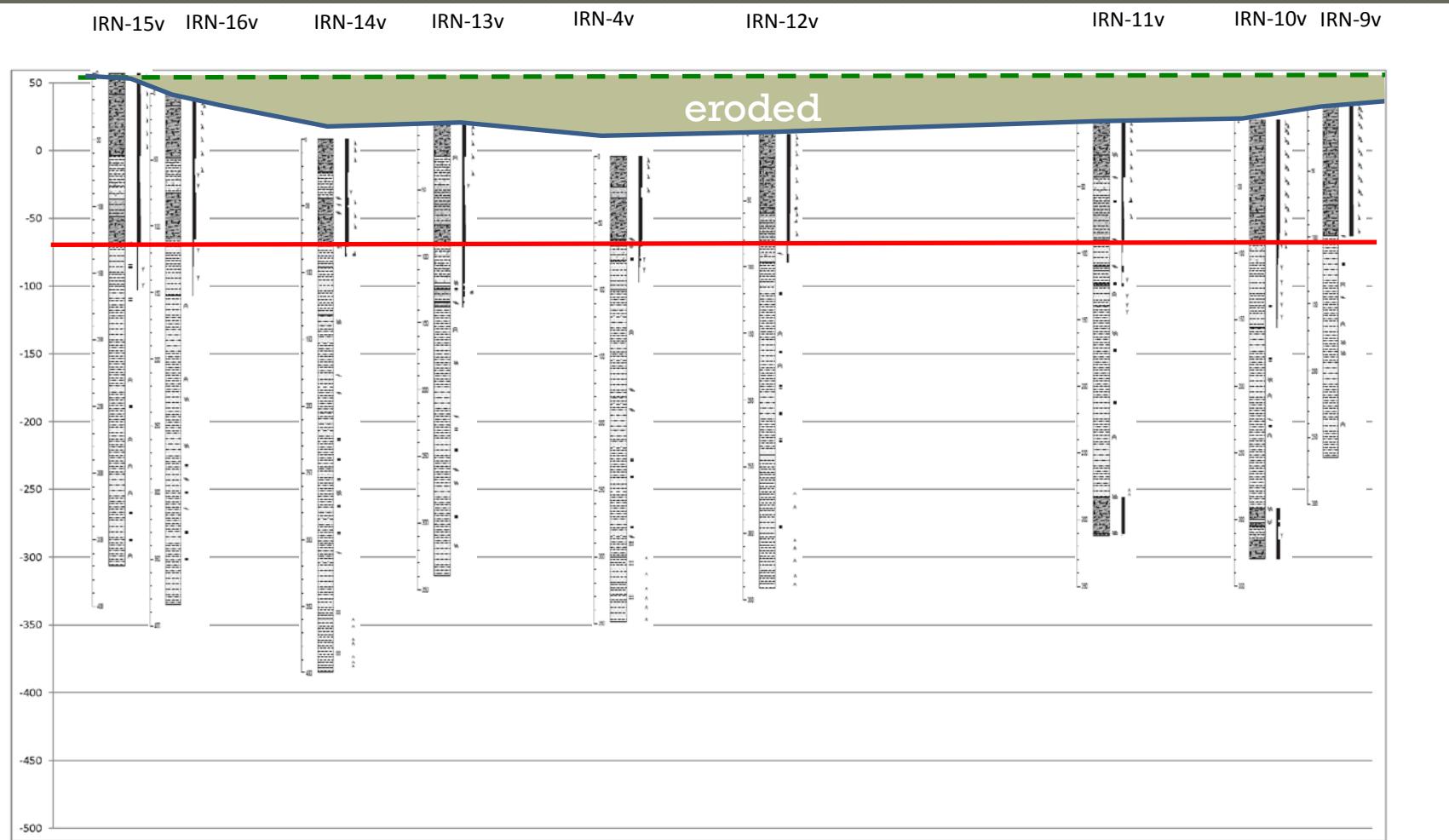
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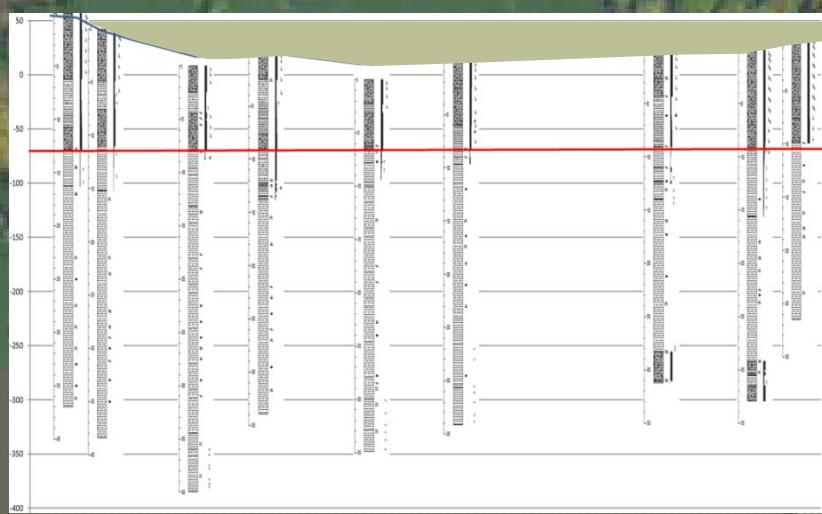
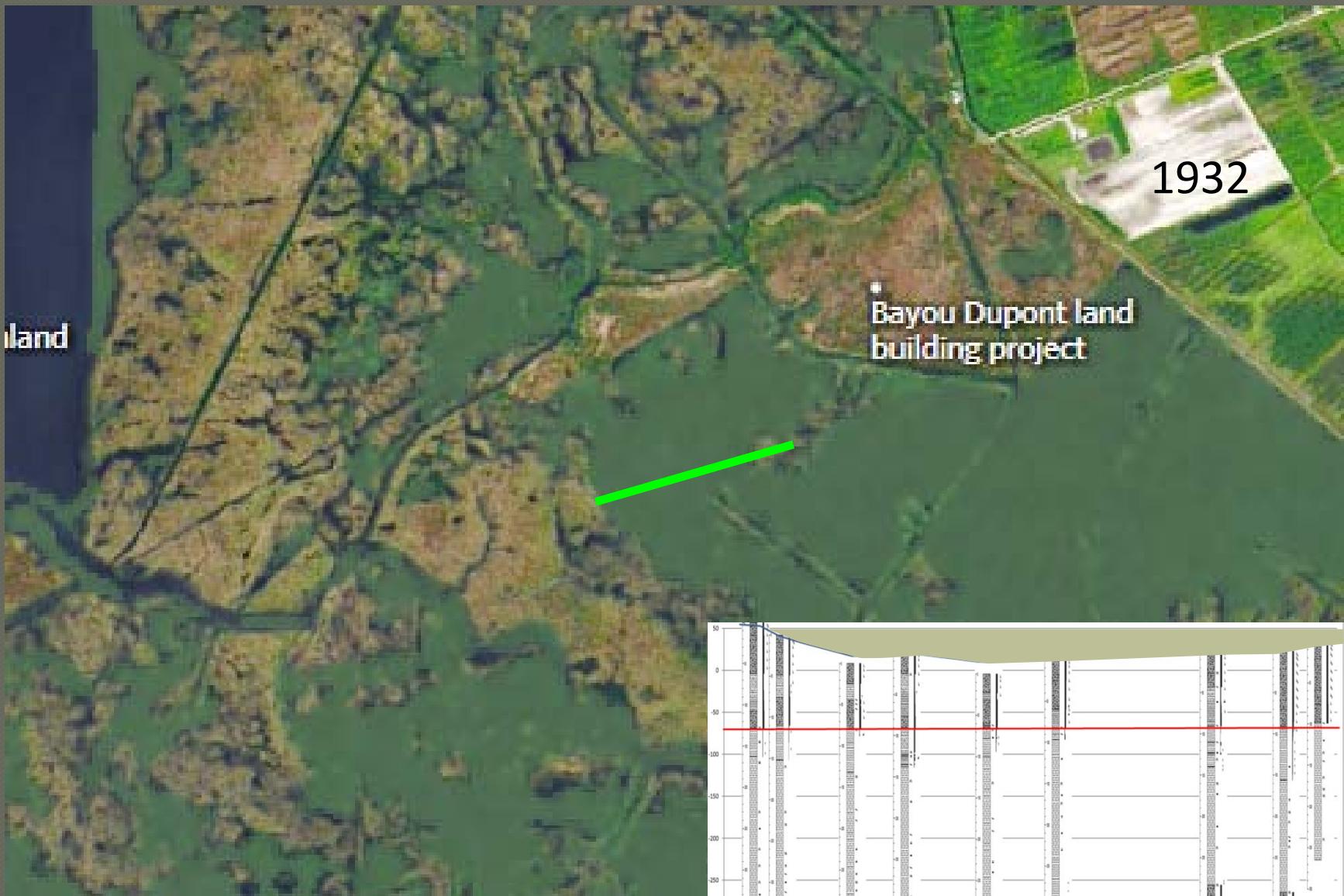
Myrtle Grove Area

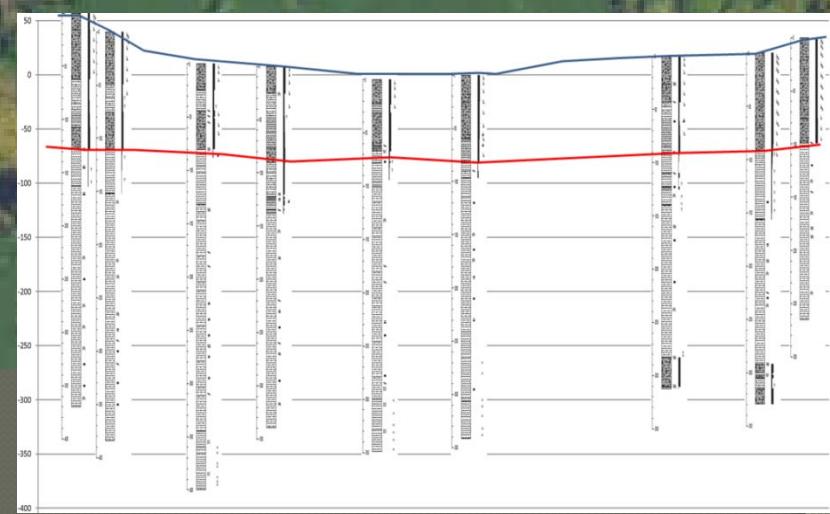


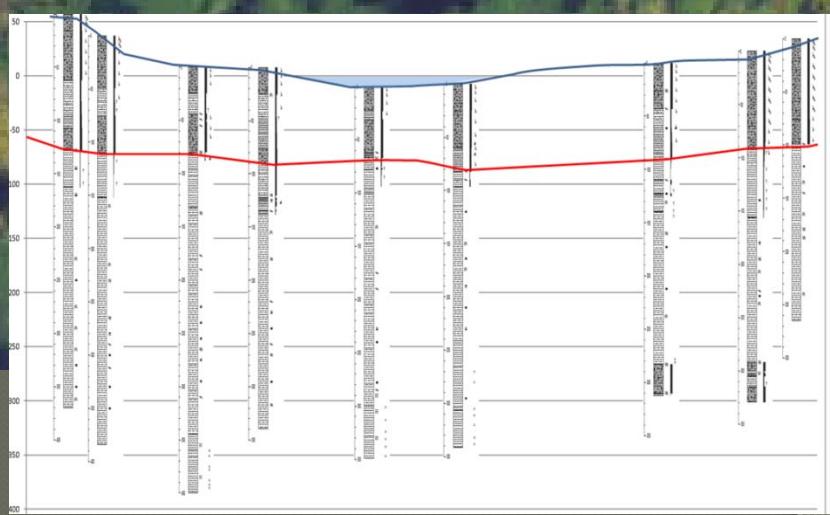
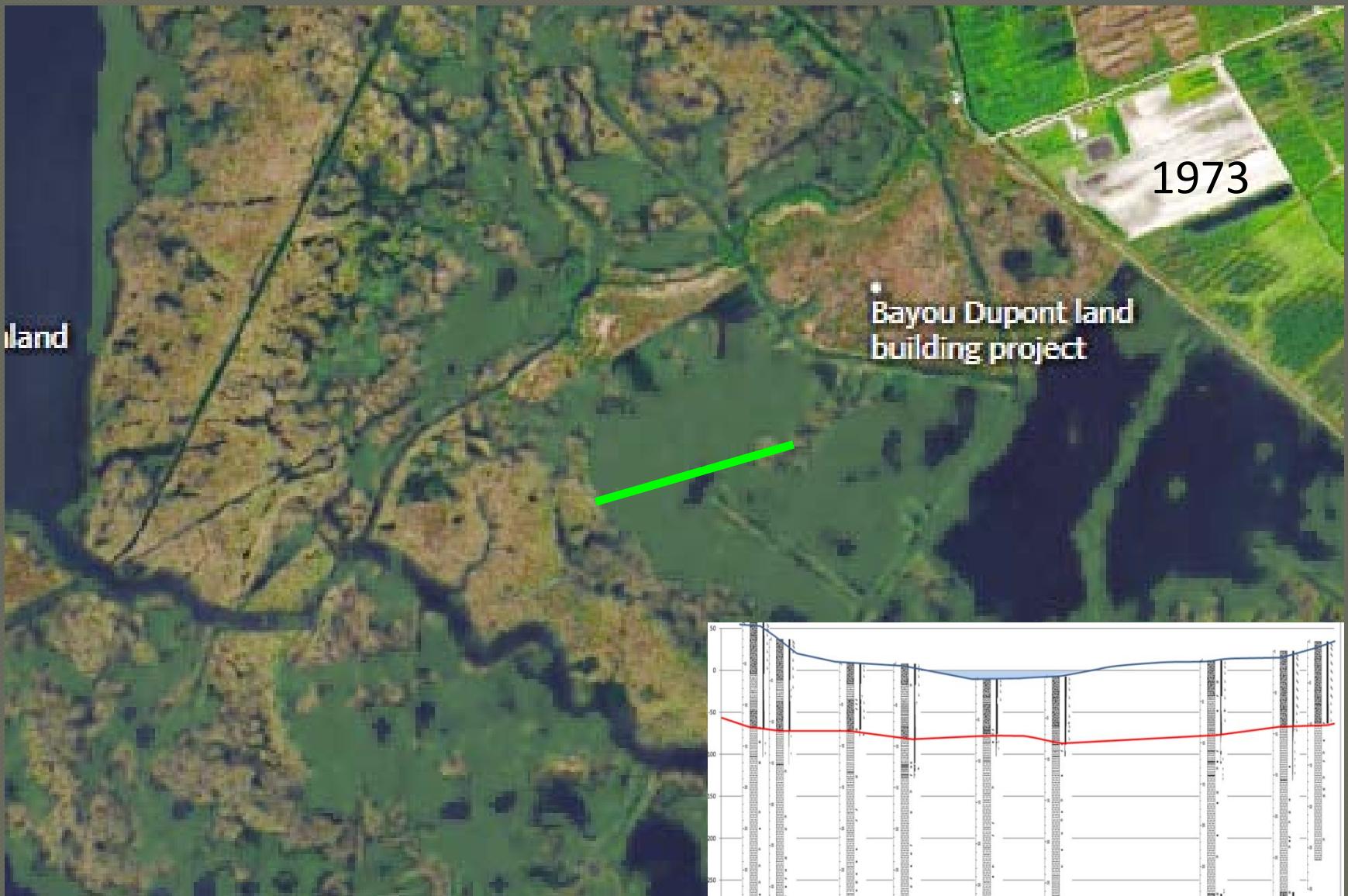


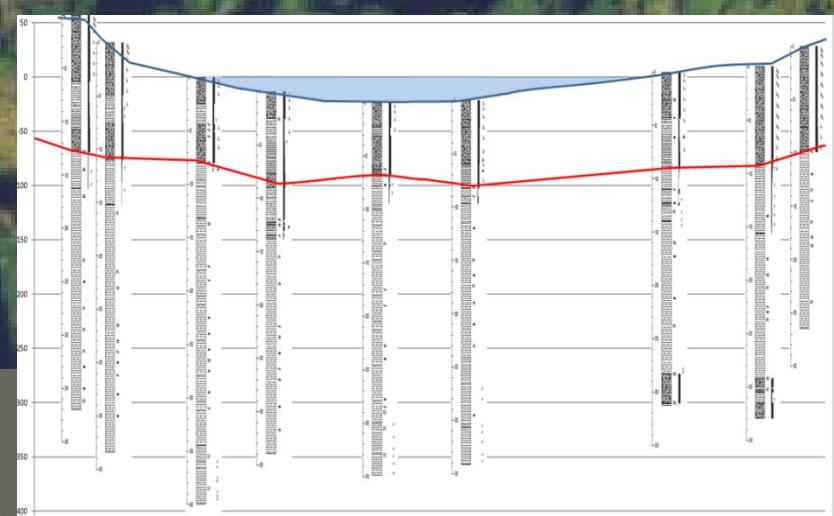
Morton, et.al., 2009 Recent Subsidence and Erosion at Diverse Wetland Sites in the Southeastern Mississippi delta Plain U.S.G.S. Open-File Report 2009-1158

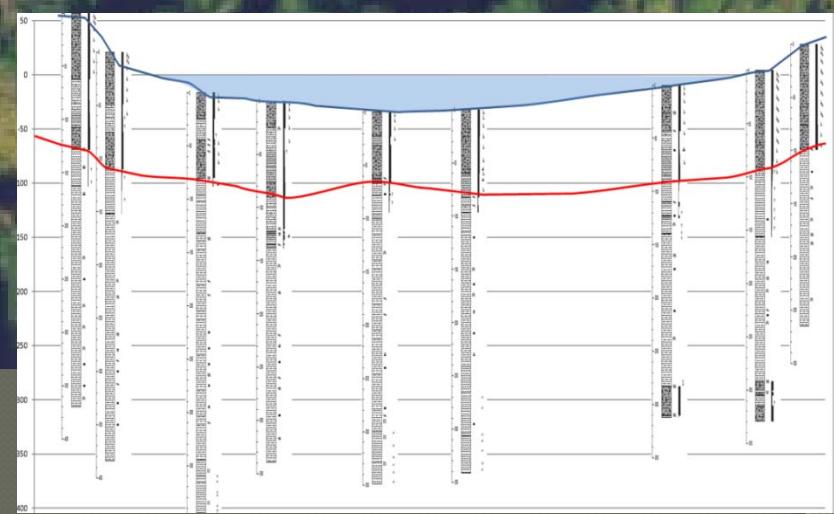


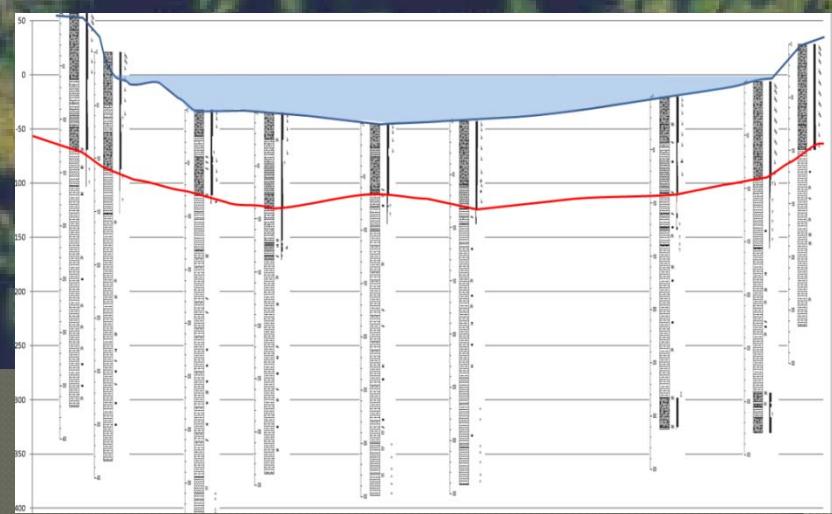
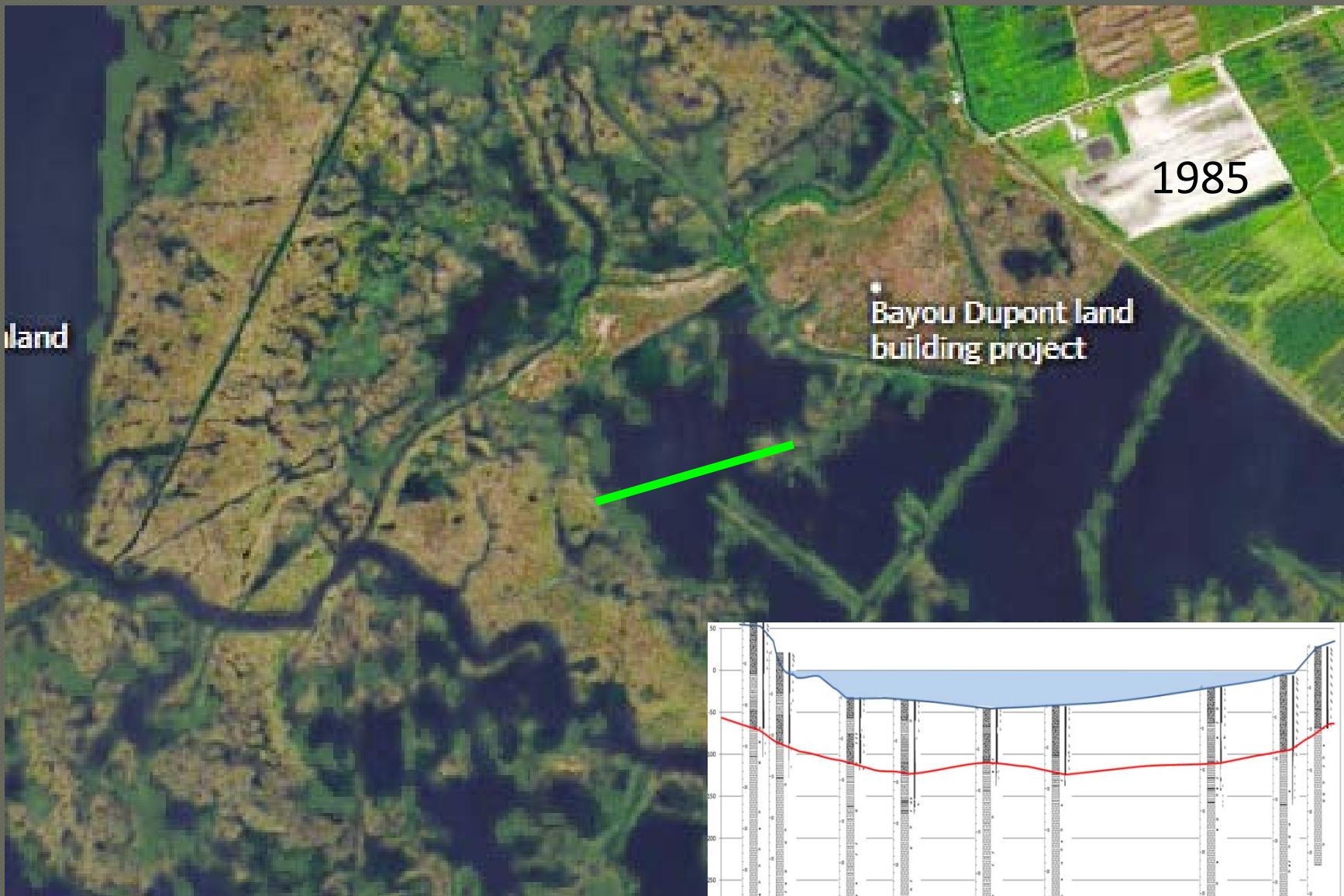


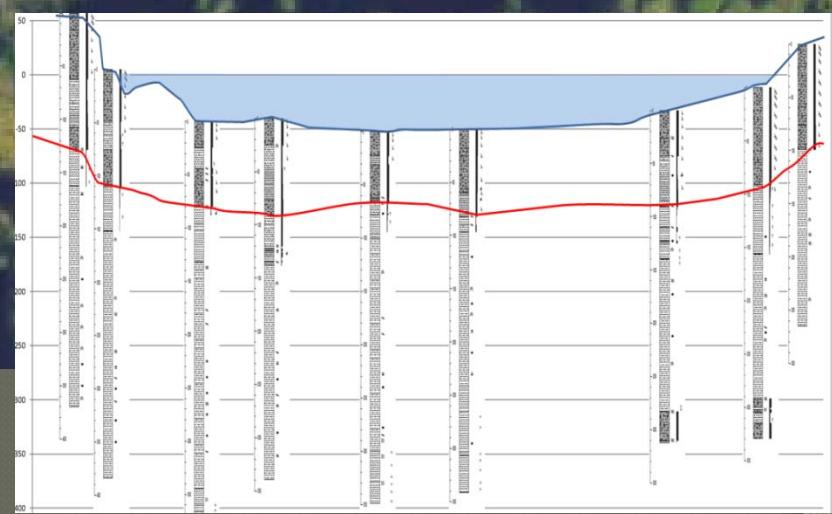
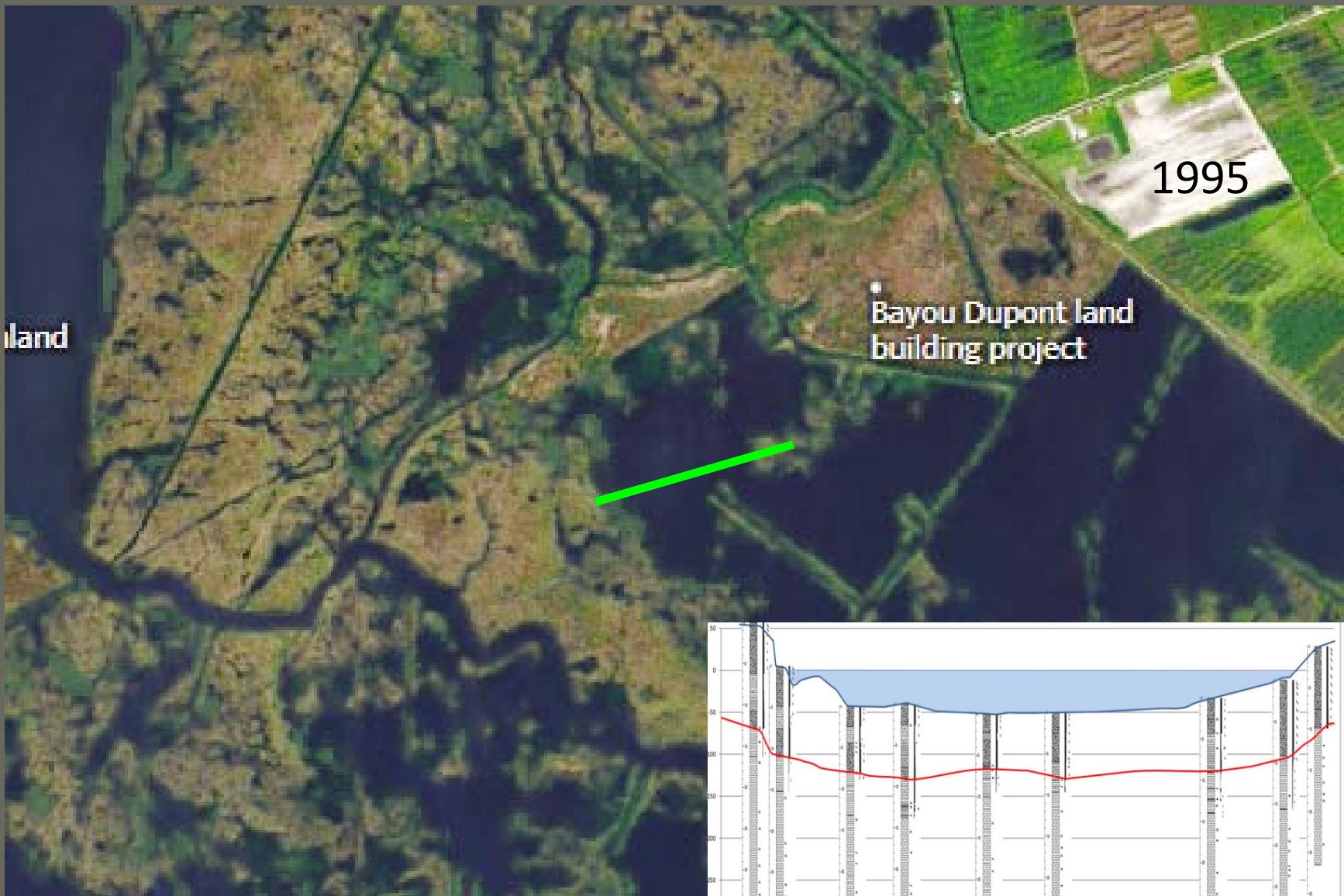


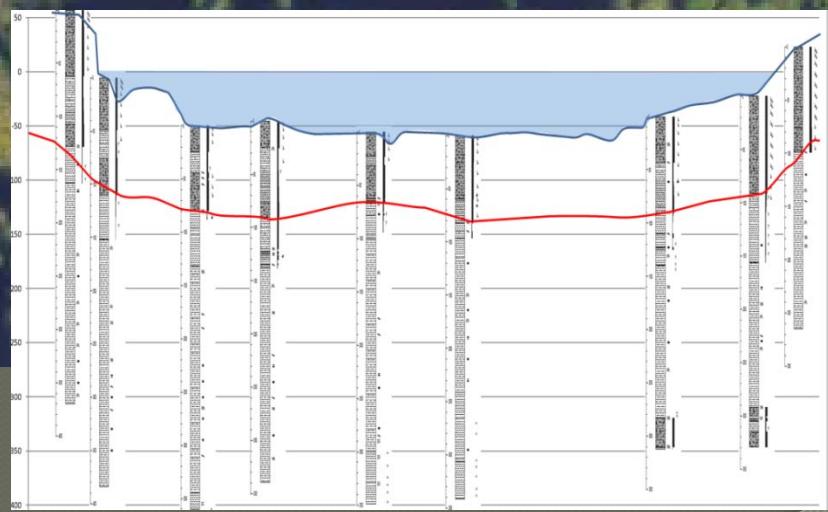
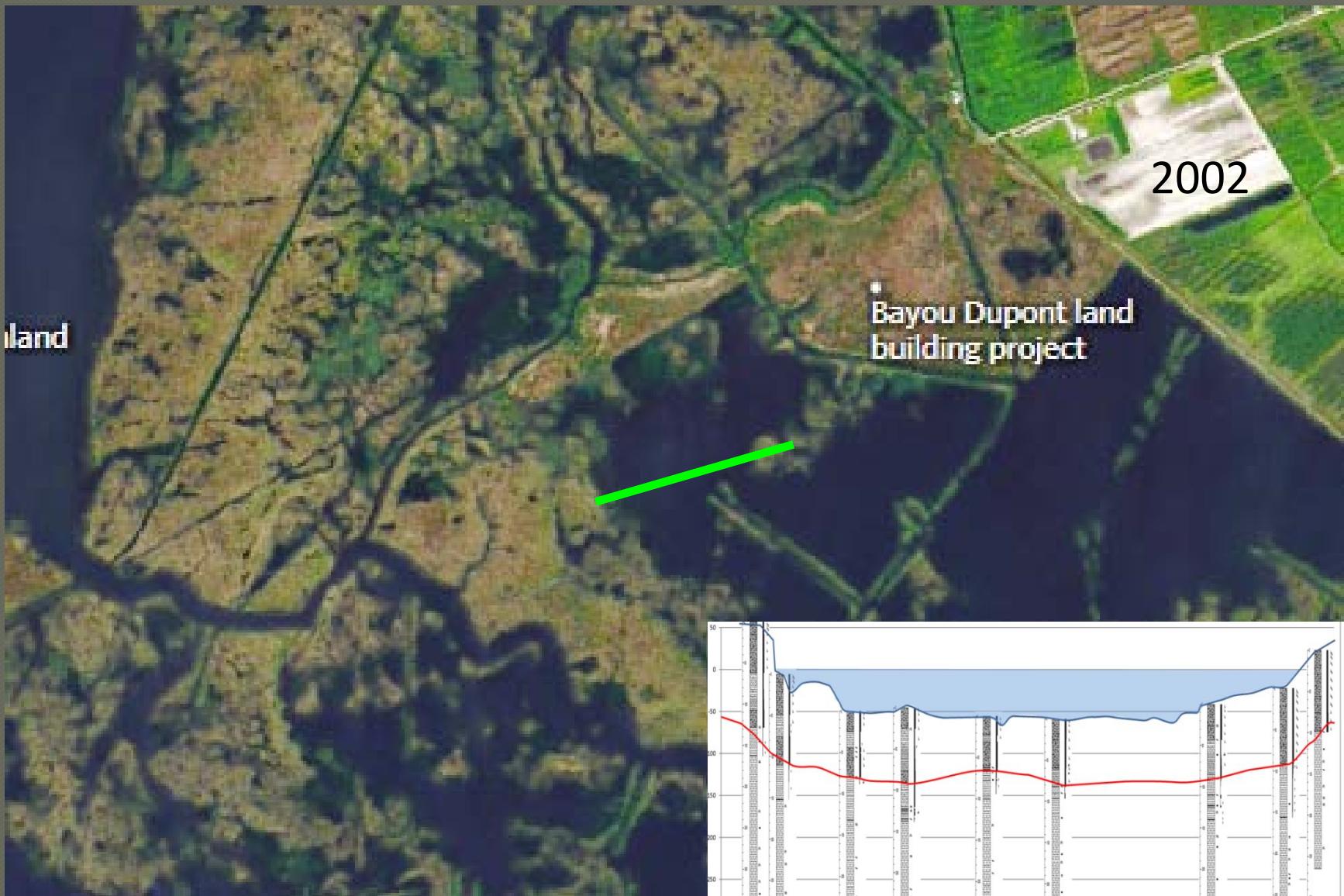


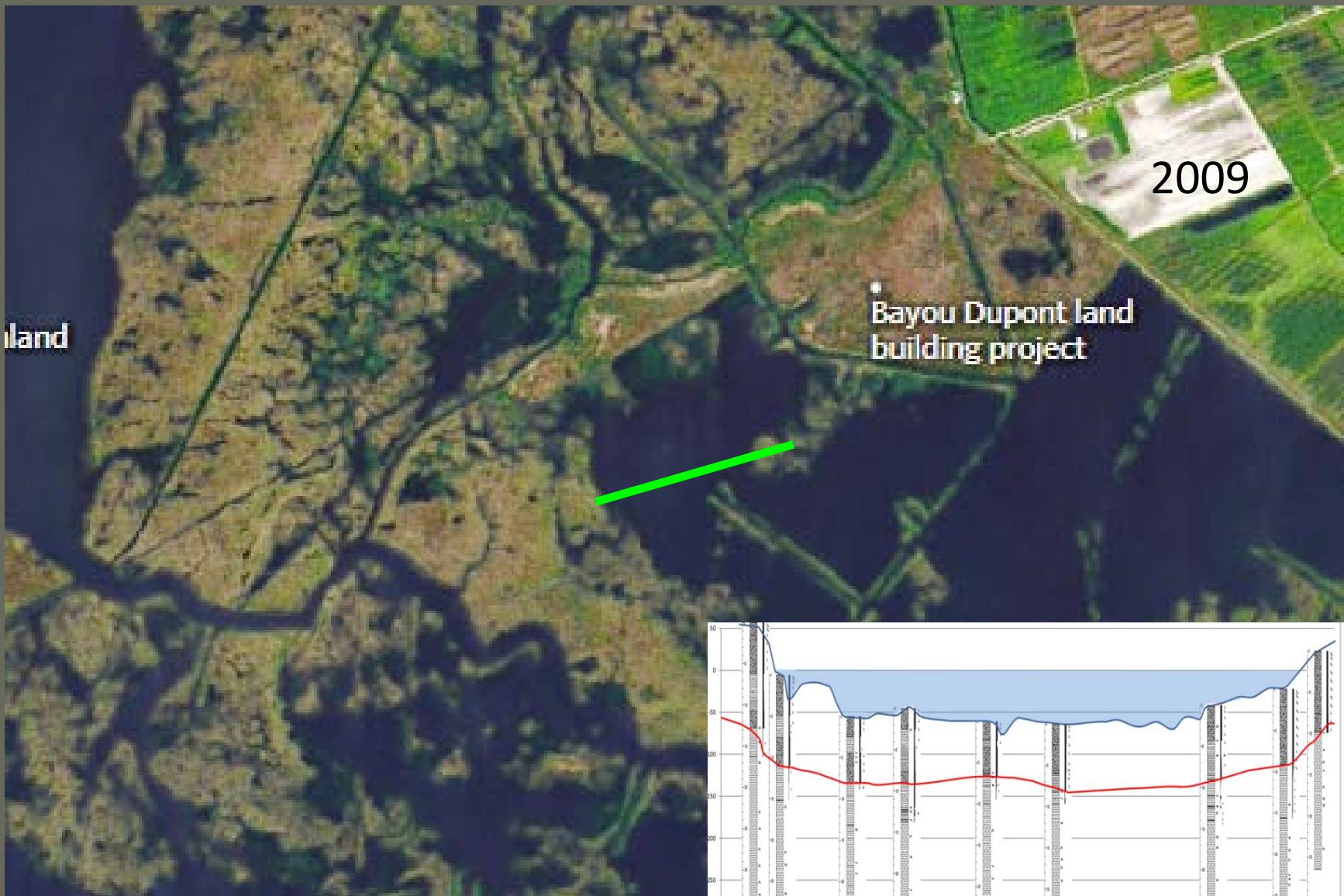




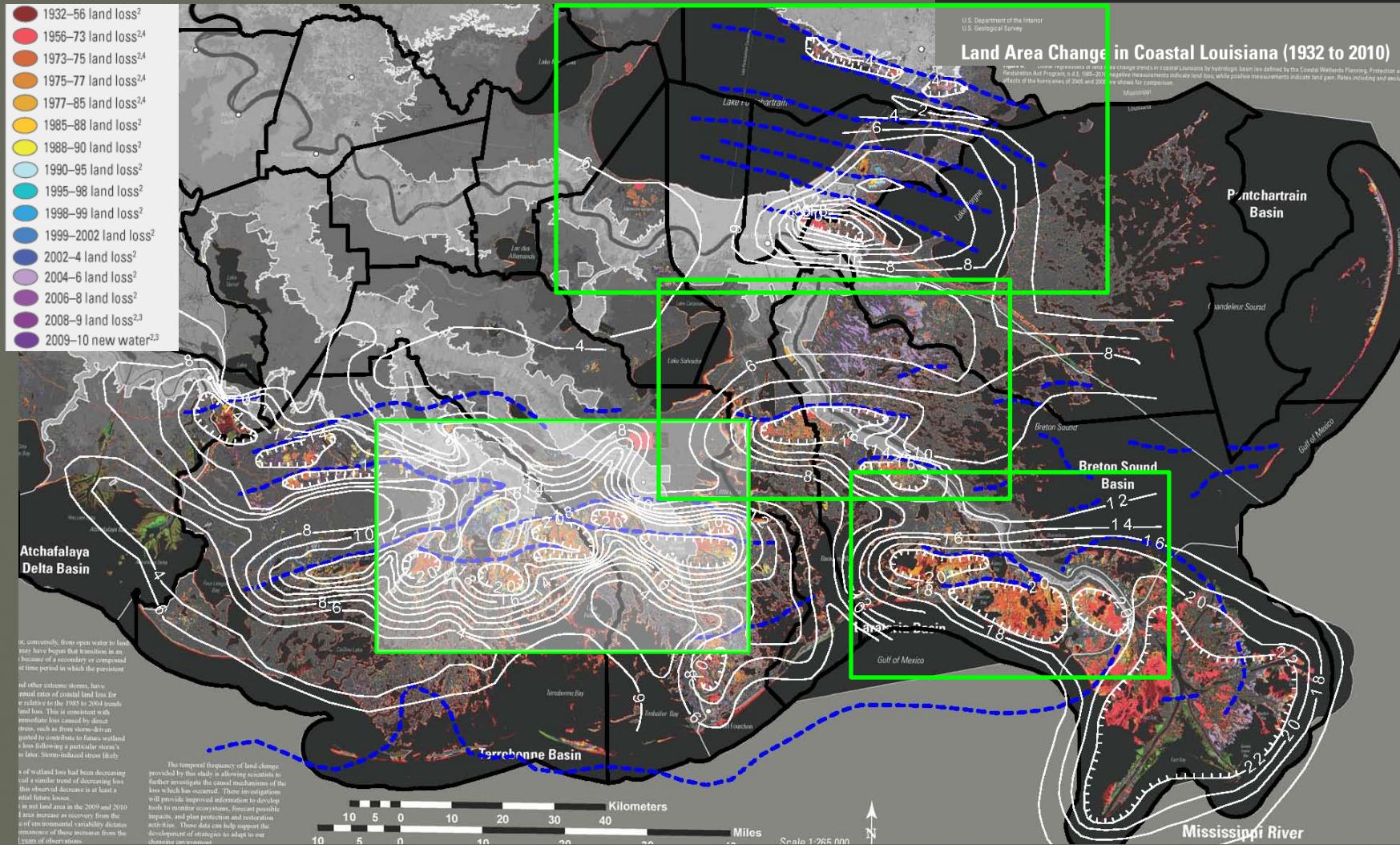


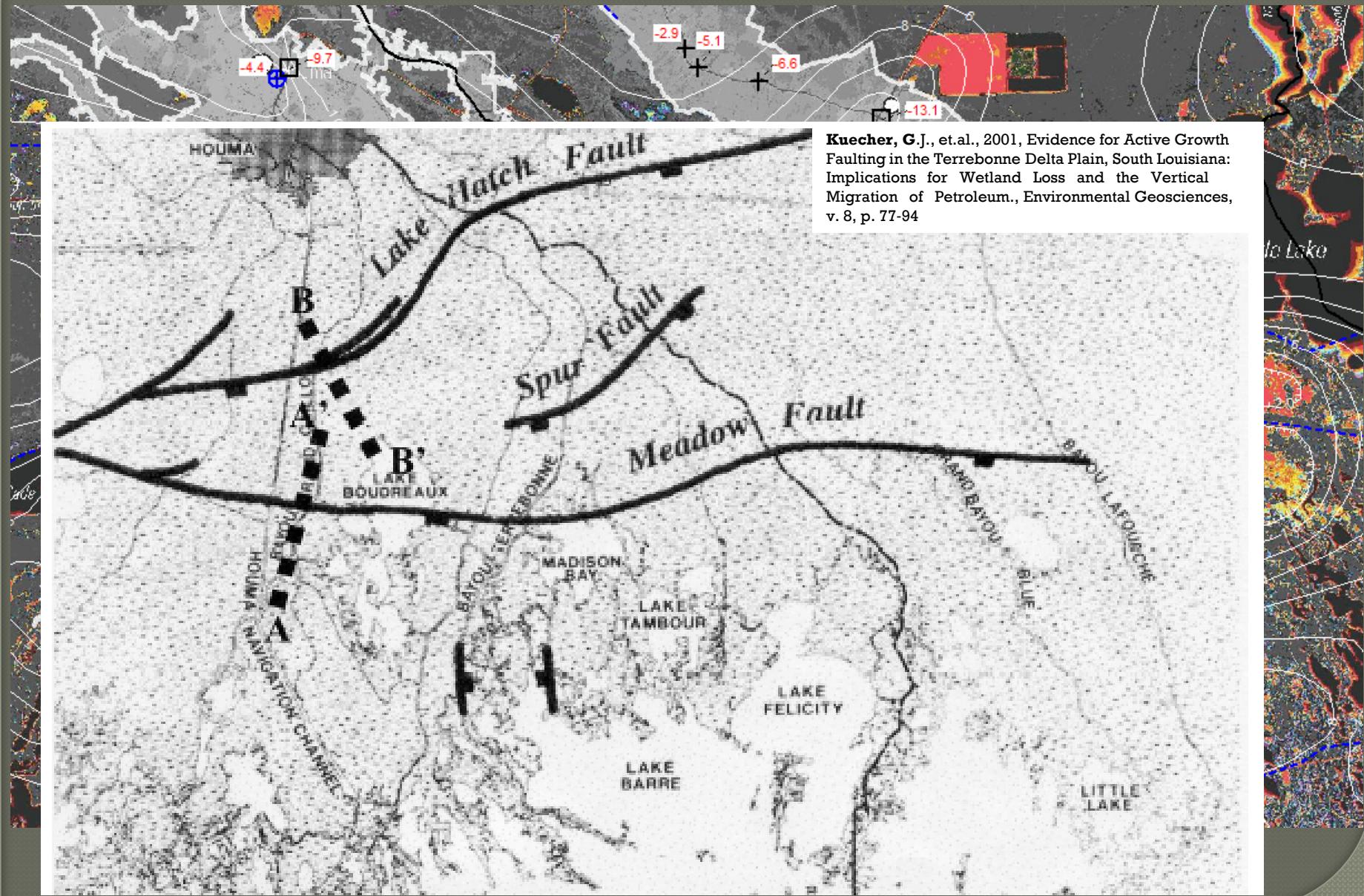


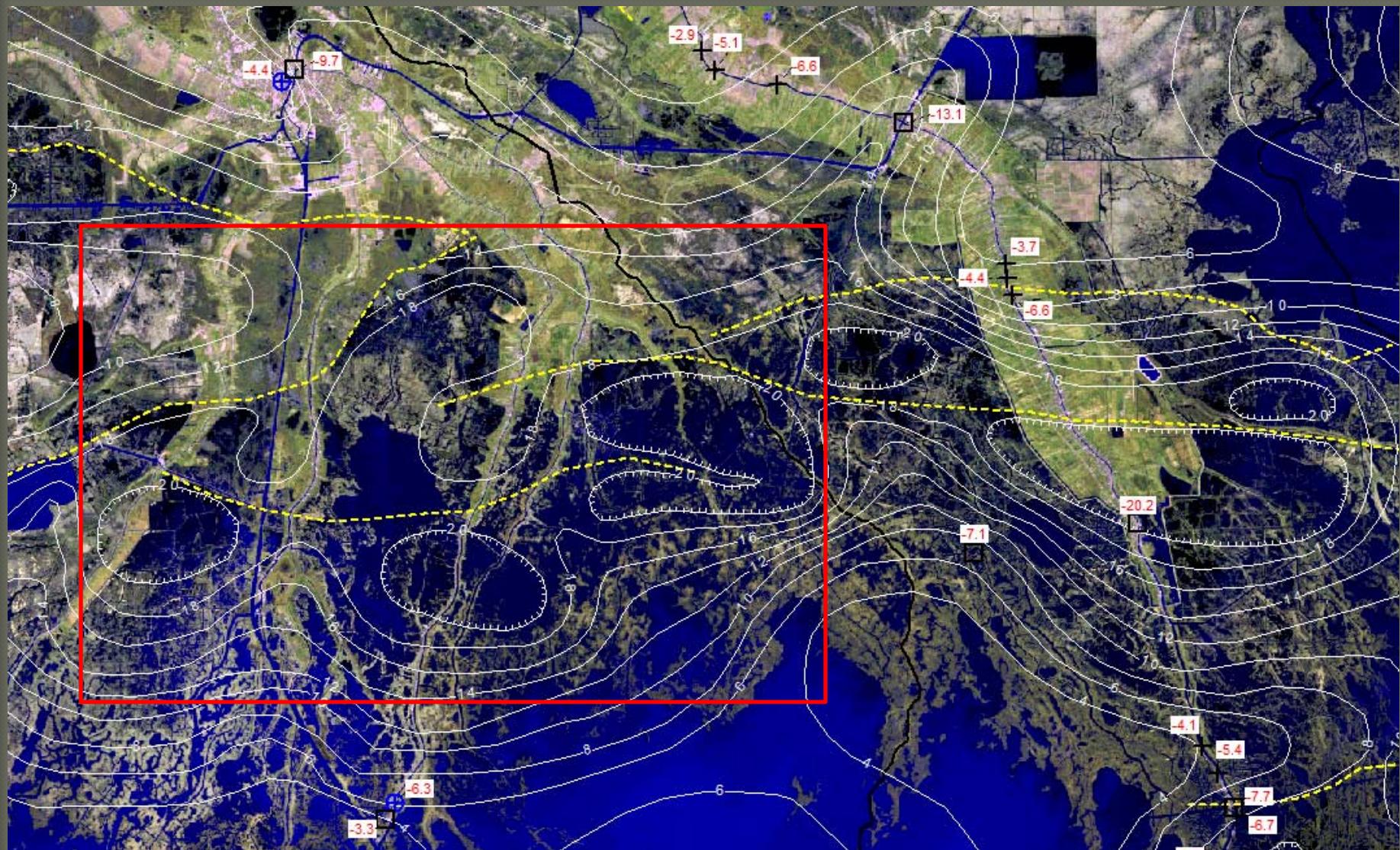




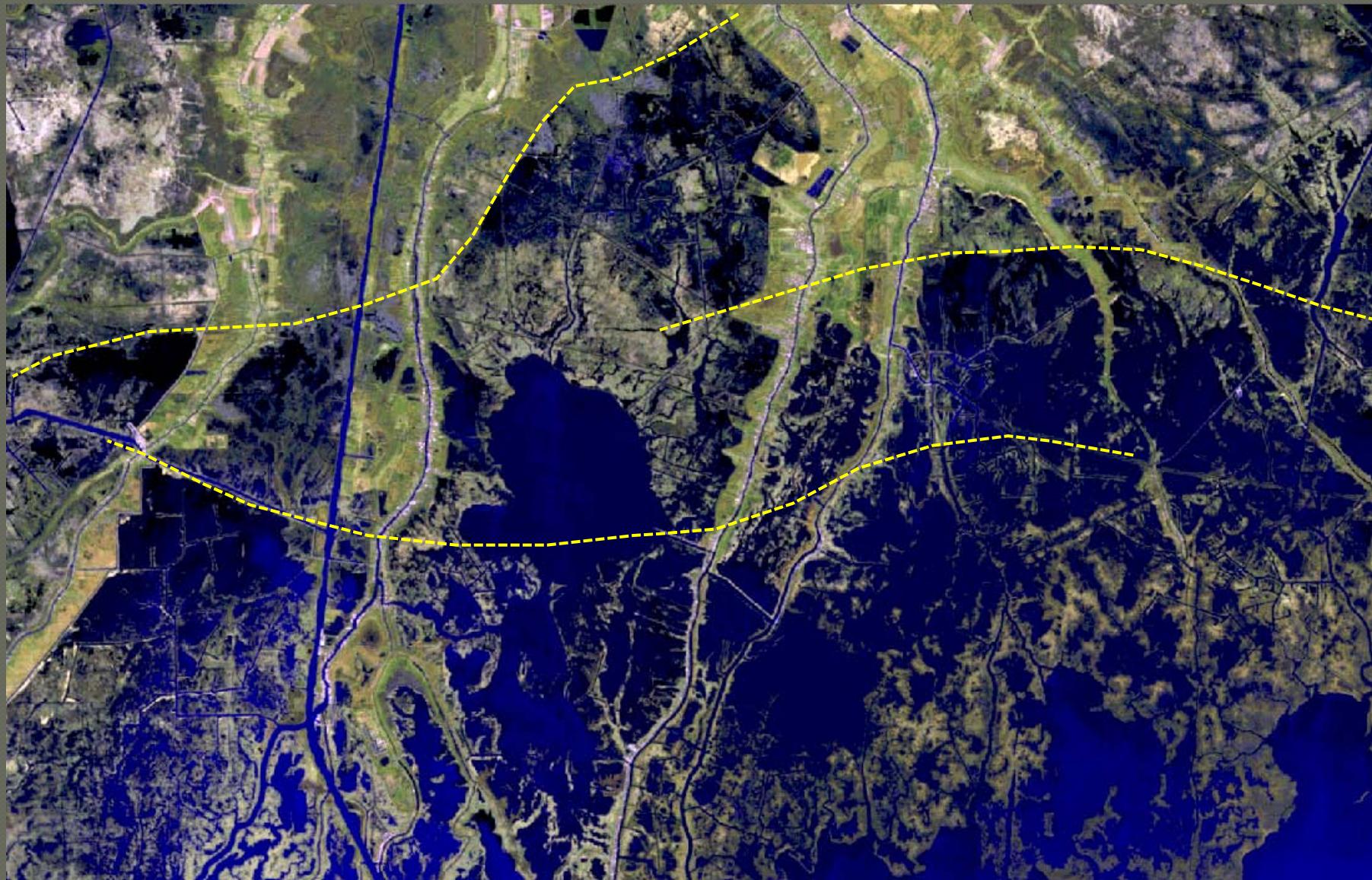




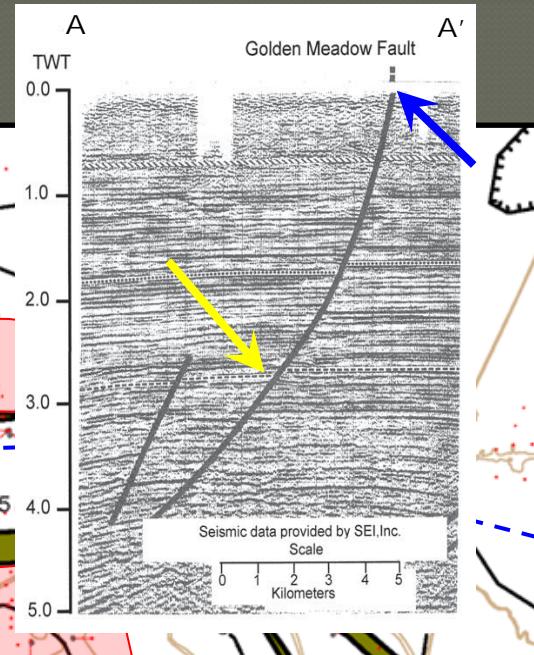
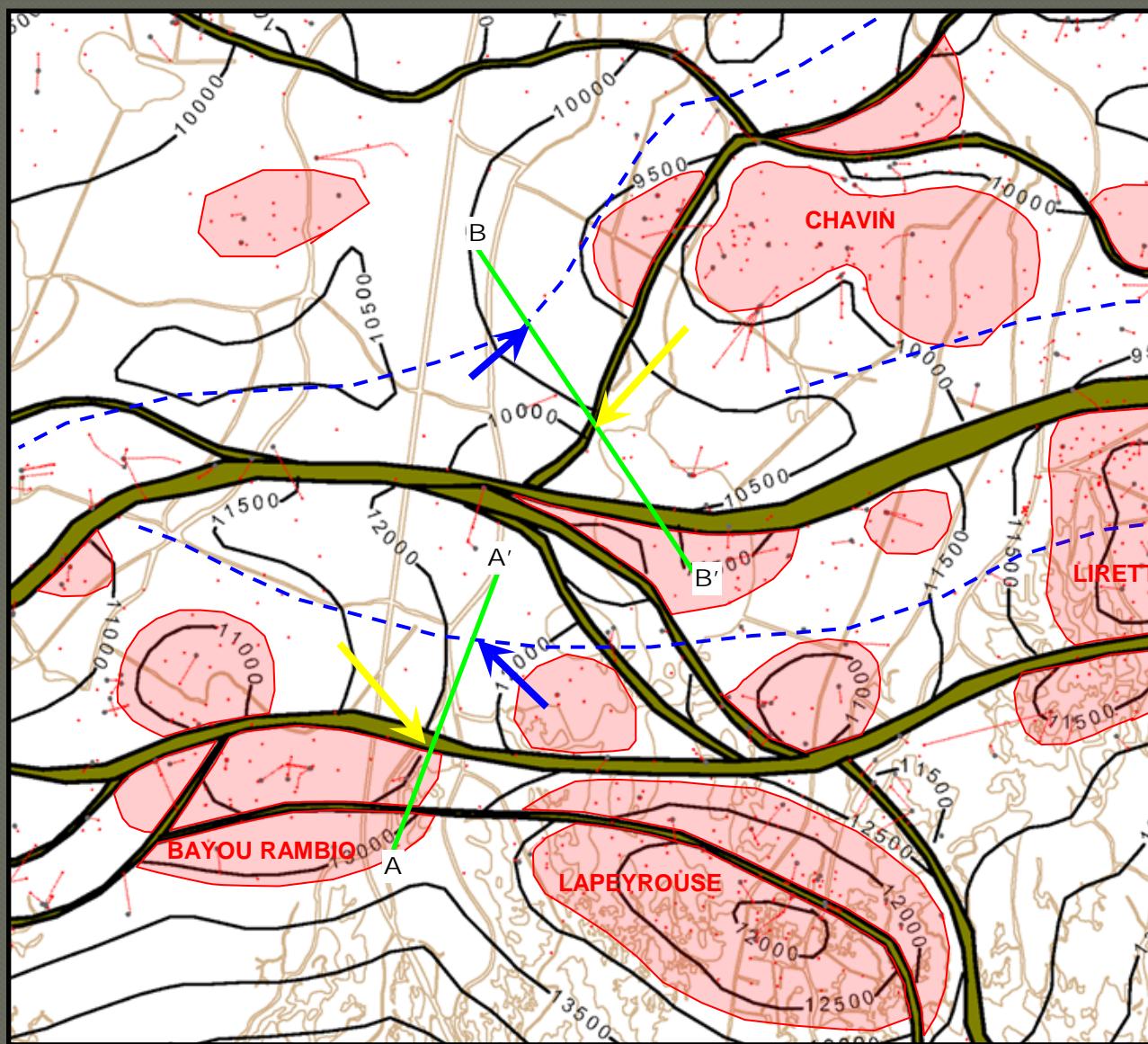




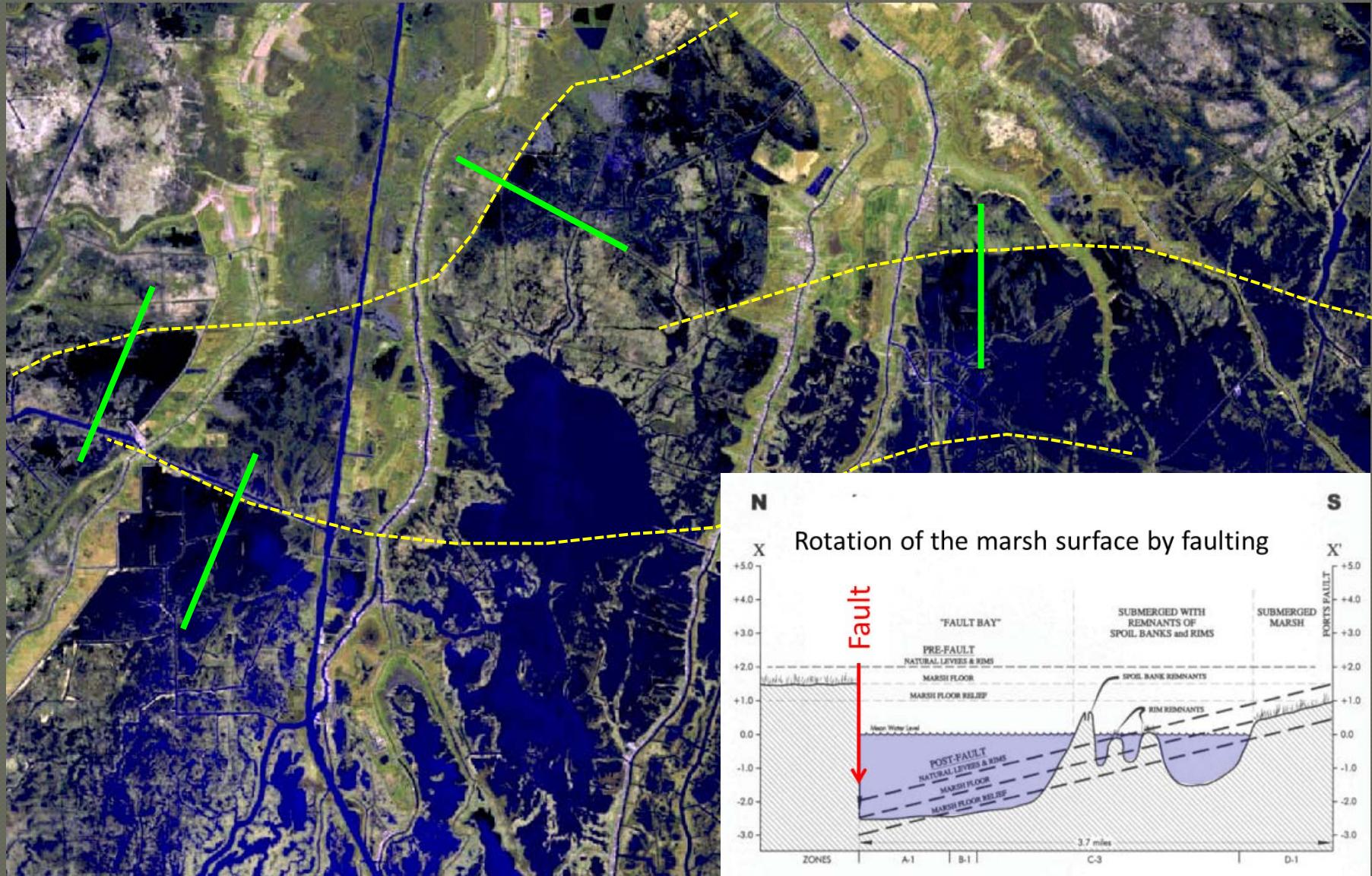
Marsh Subsidence Due to Faulting



Middle Miocene Fields

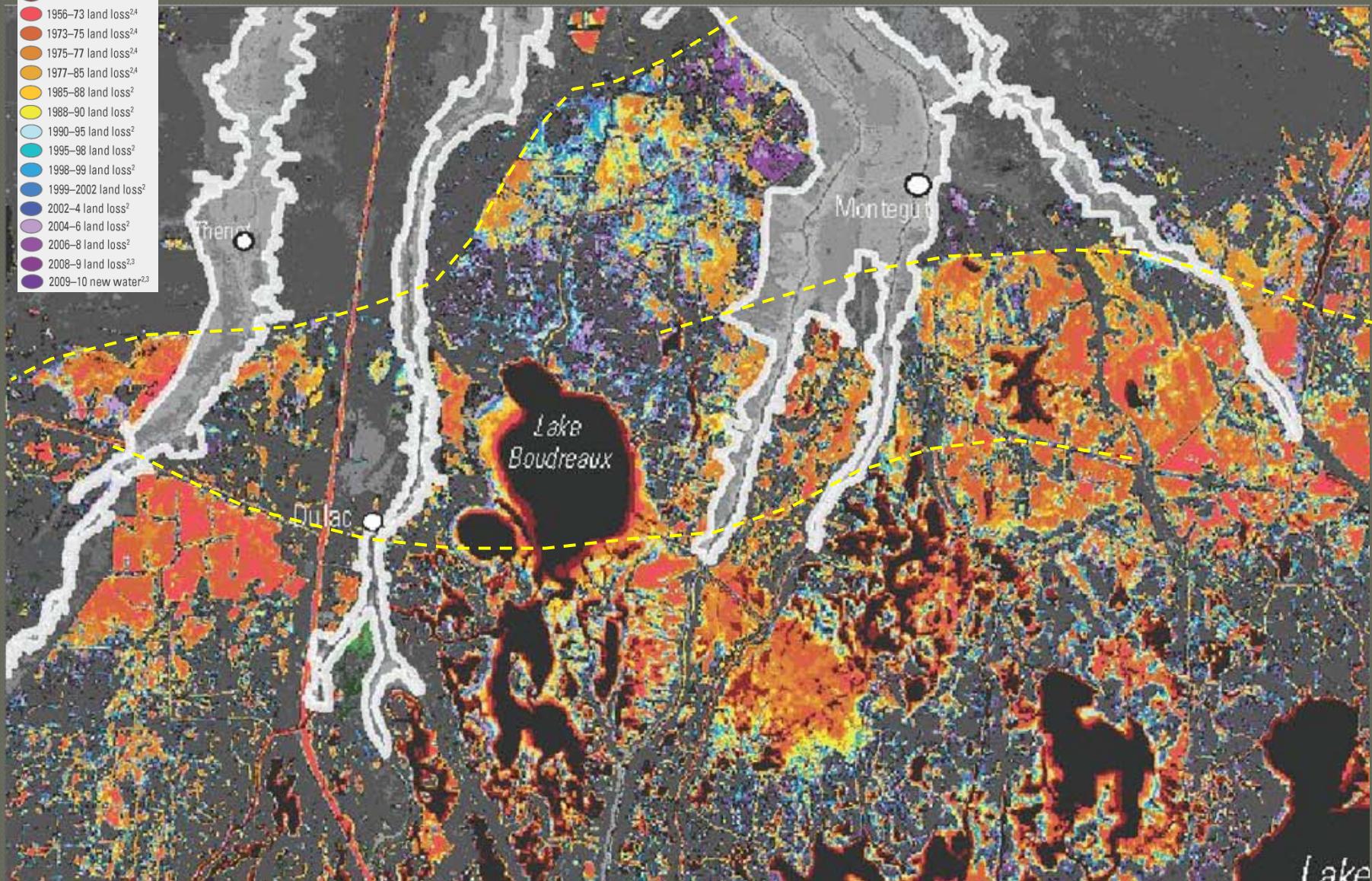


Marsh Subsidence Due to Faulting



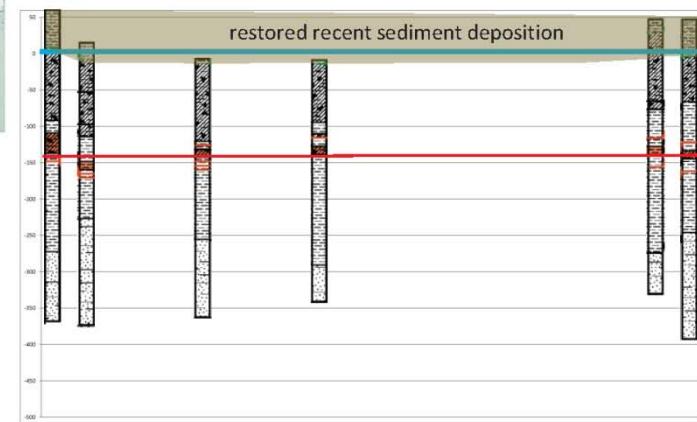
Surface Fault Traces

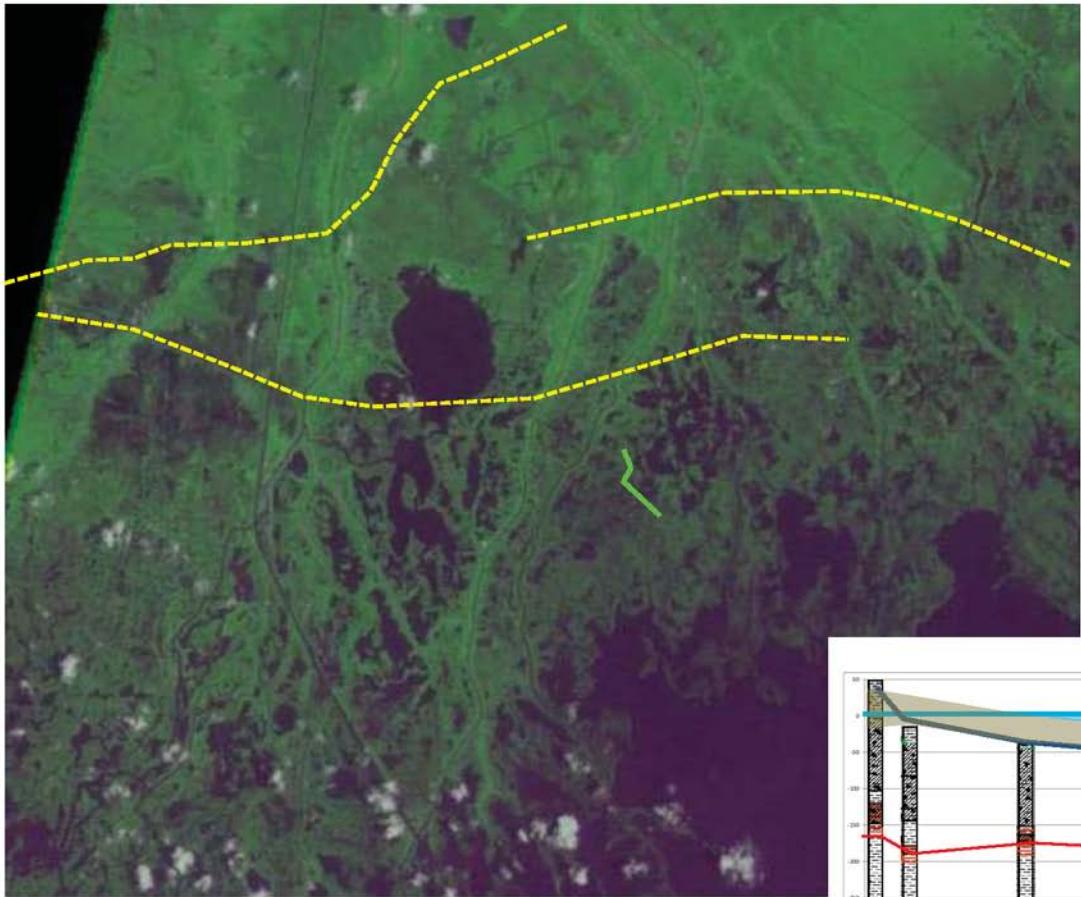
- 1932–56 land loss²
- 1956–73 land loss²⁴
- 1973–75 land loss²⁴
- 1975–77 land loss²⁴
- 1977–85 land loss²⁴
- 1985–88 land loss²
- 1988–90 land loss²
- 1990–95 land loss²
- 1995–98 land loss²
- 1998–99 land loss²
- 1999–2002 land loss²
- 2002–4 land loss²
- 2004–6 land loss²
- 2006–8 land loss²
- 2008–9 land loss^{2,3}
- 2009–10 new water^{2,3}



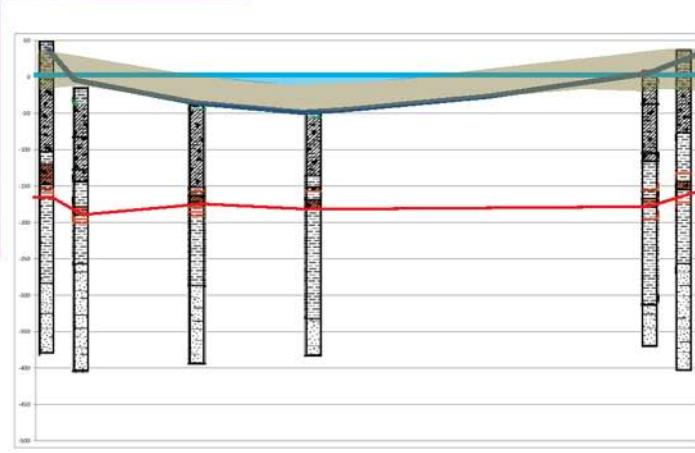


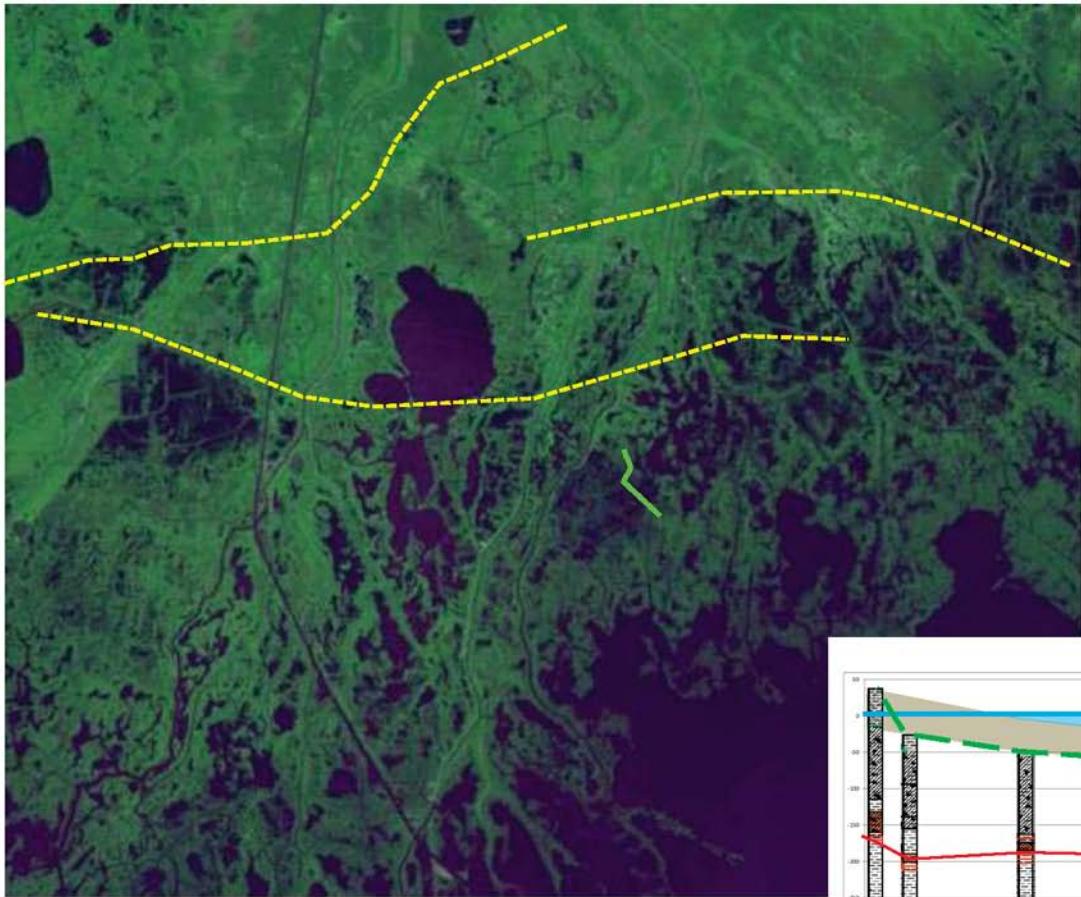
1935



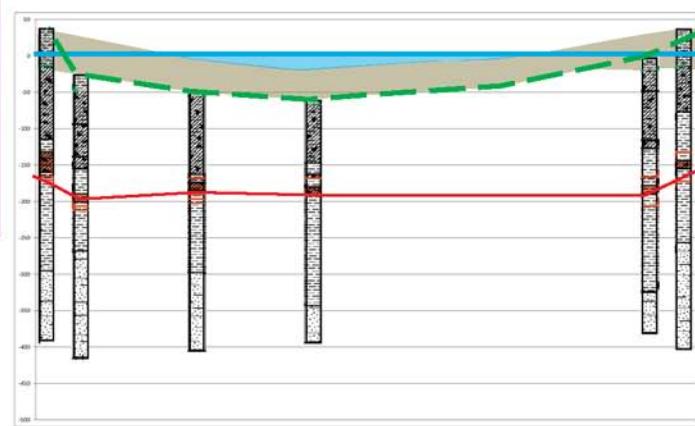


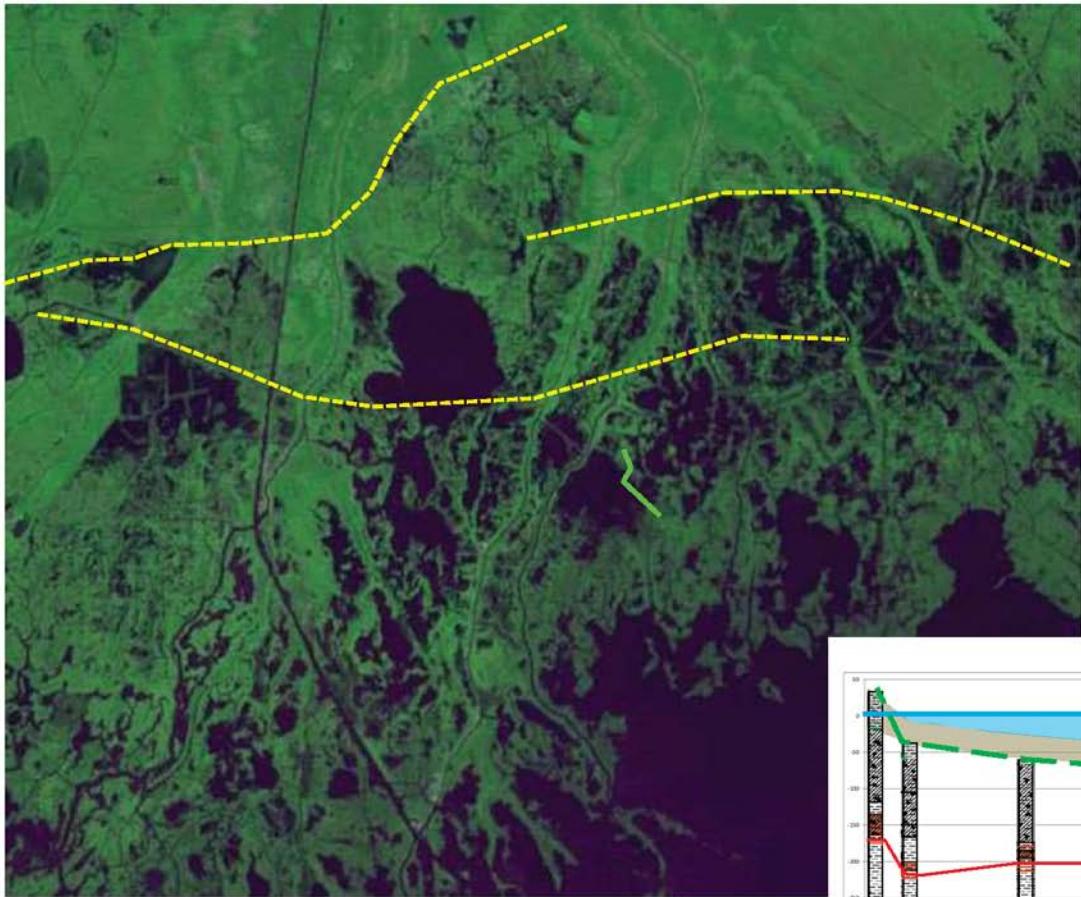
1972



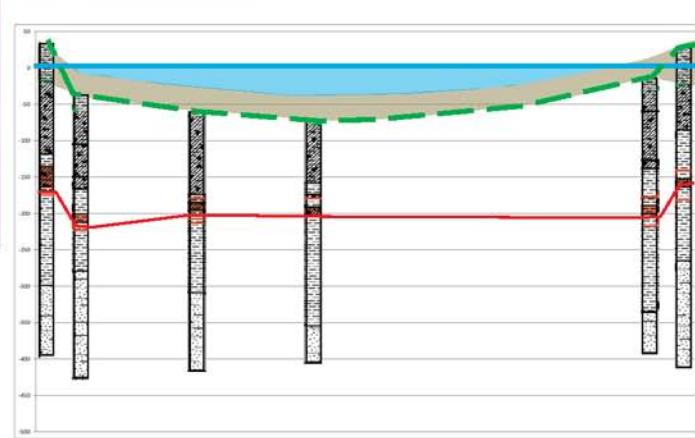


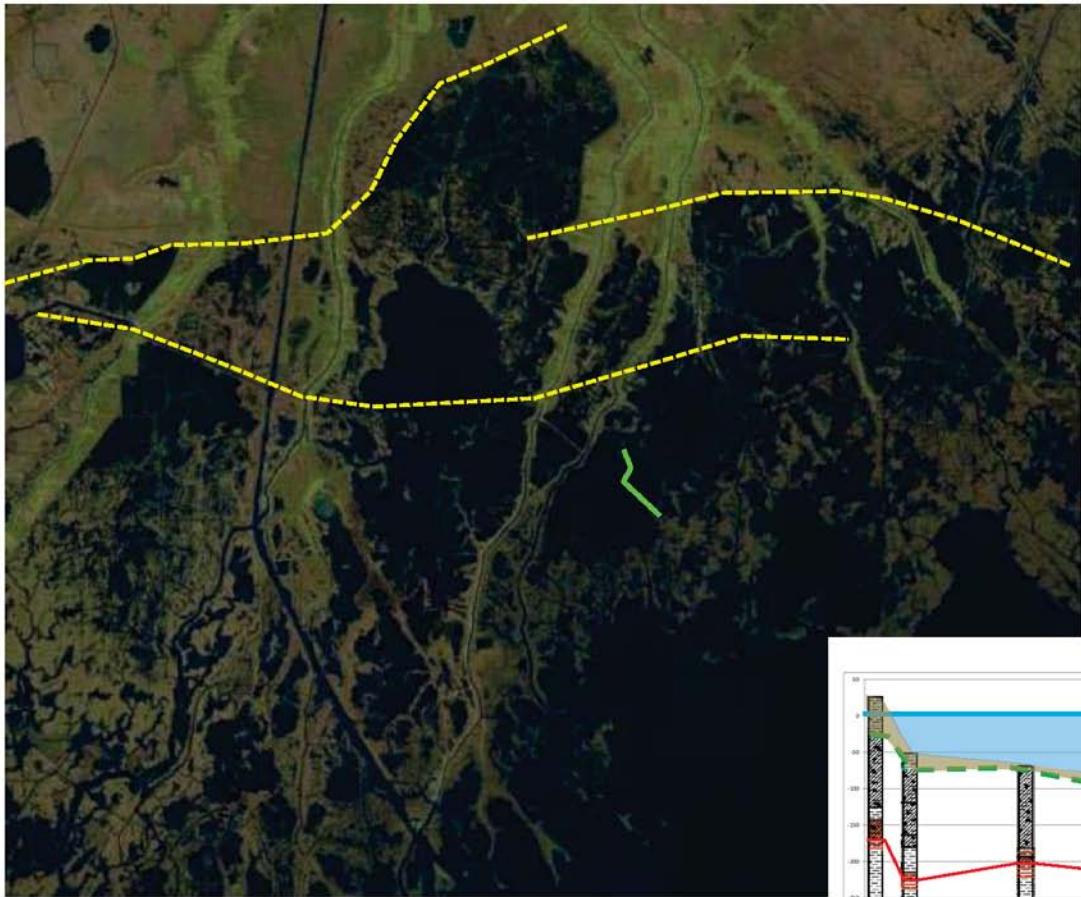
1975



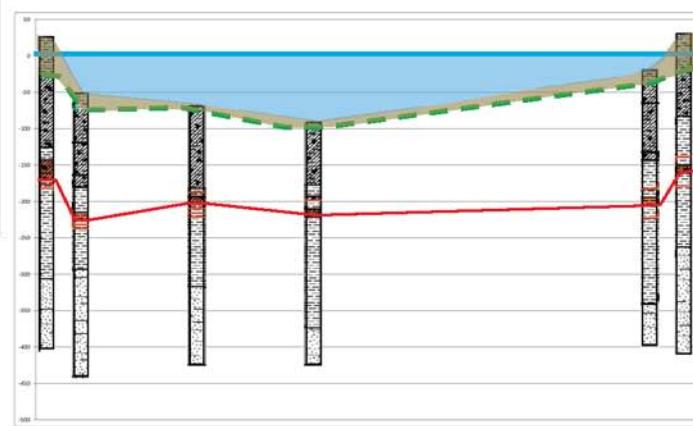


1987





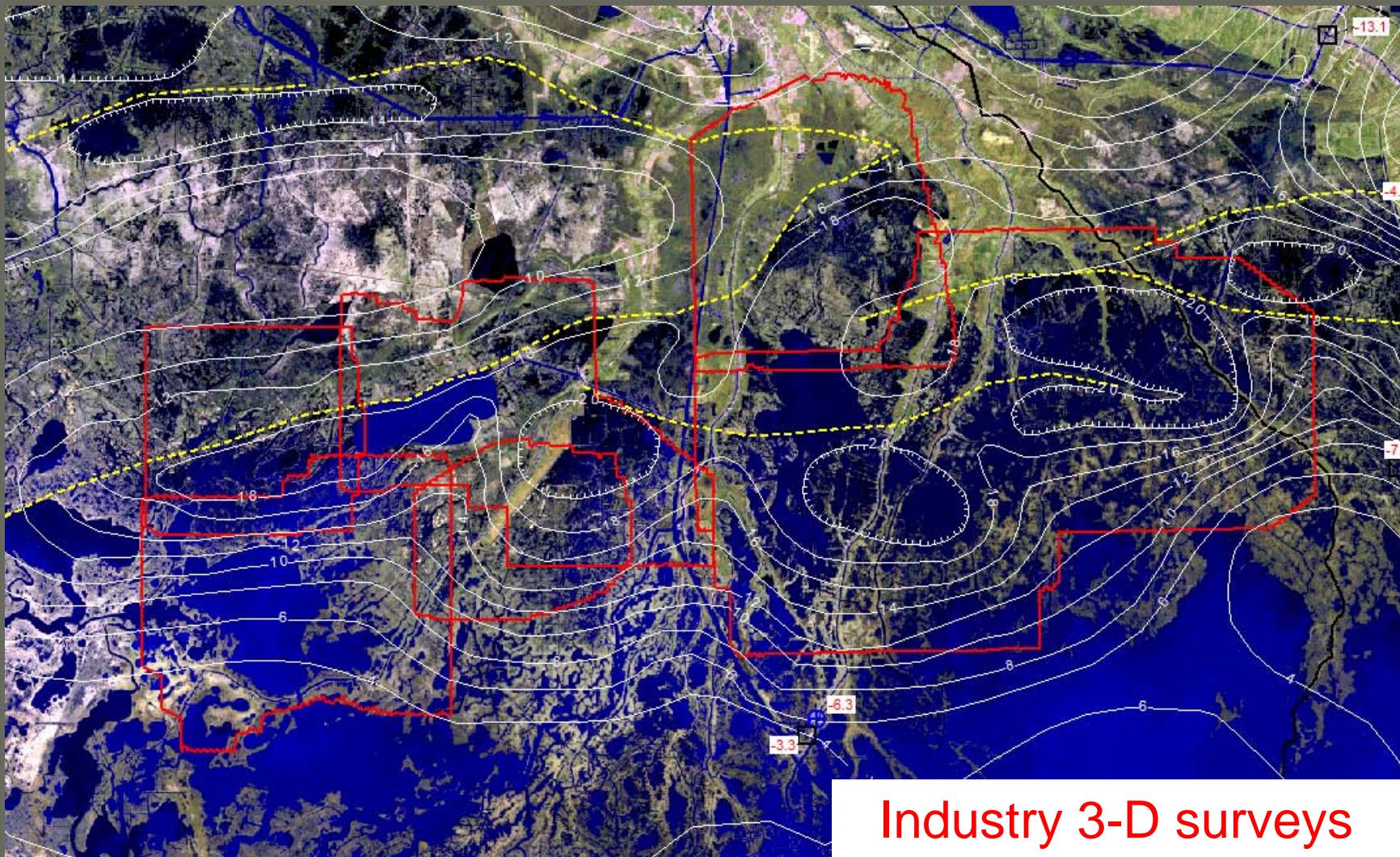
2015



The Next Project

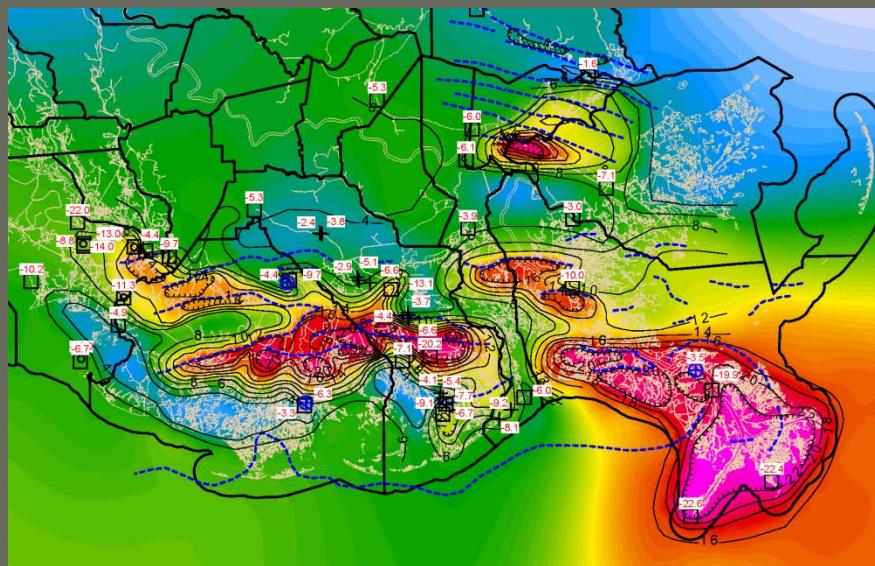
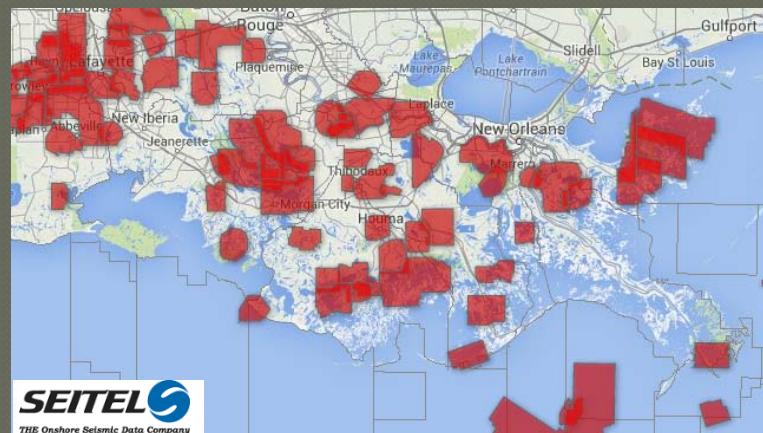


The Next Project



Building the Map

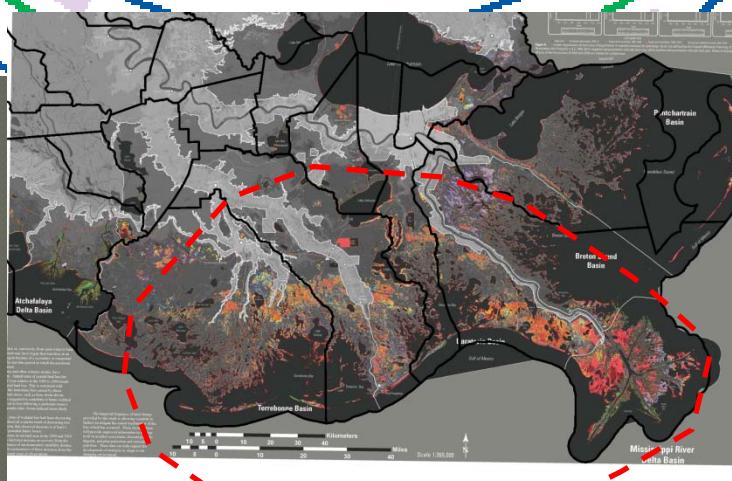
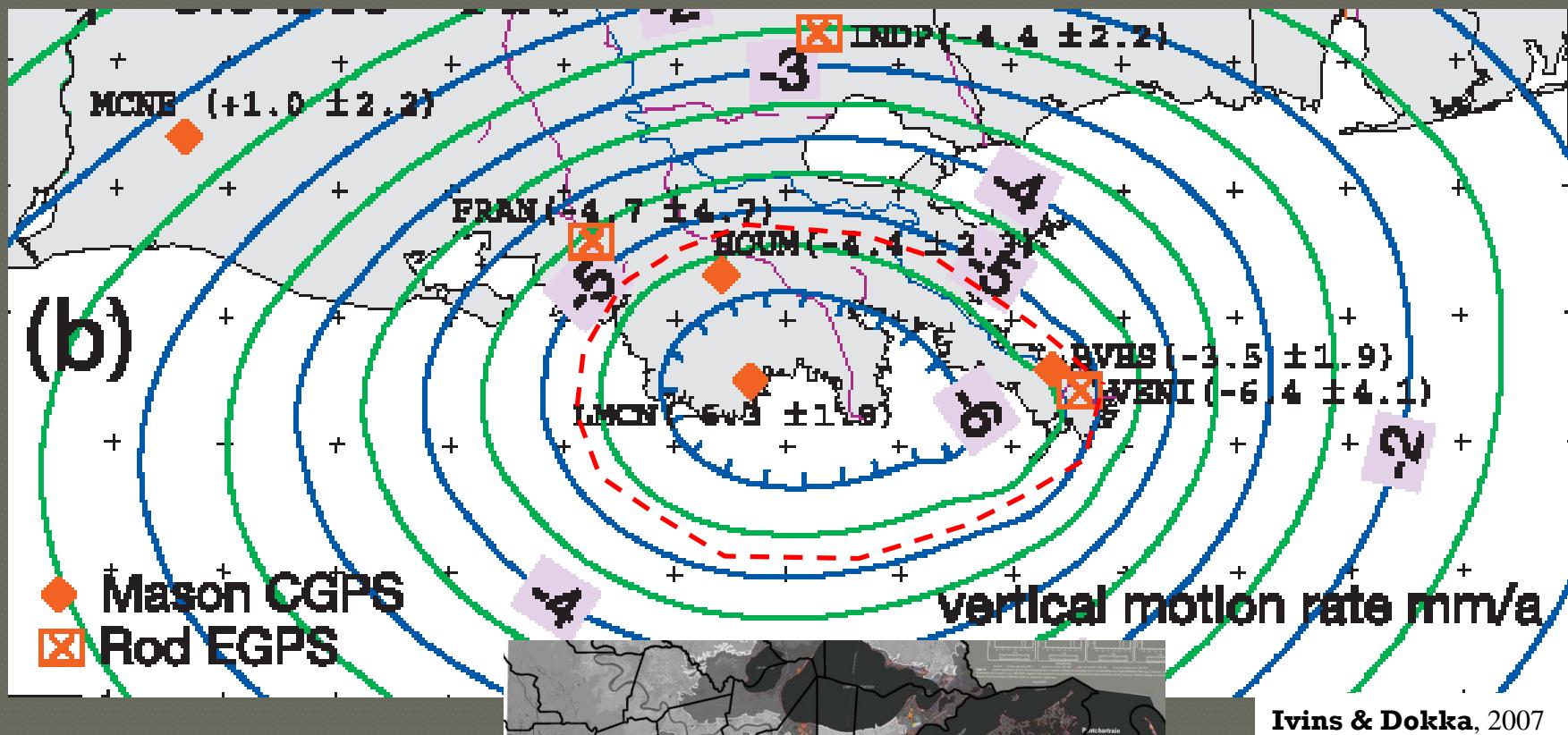
- a cooperative effort

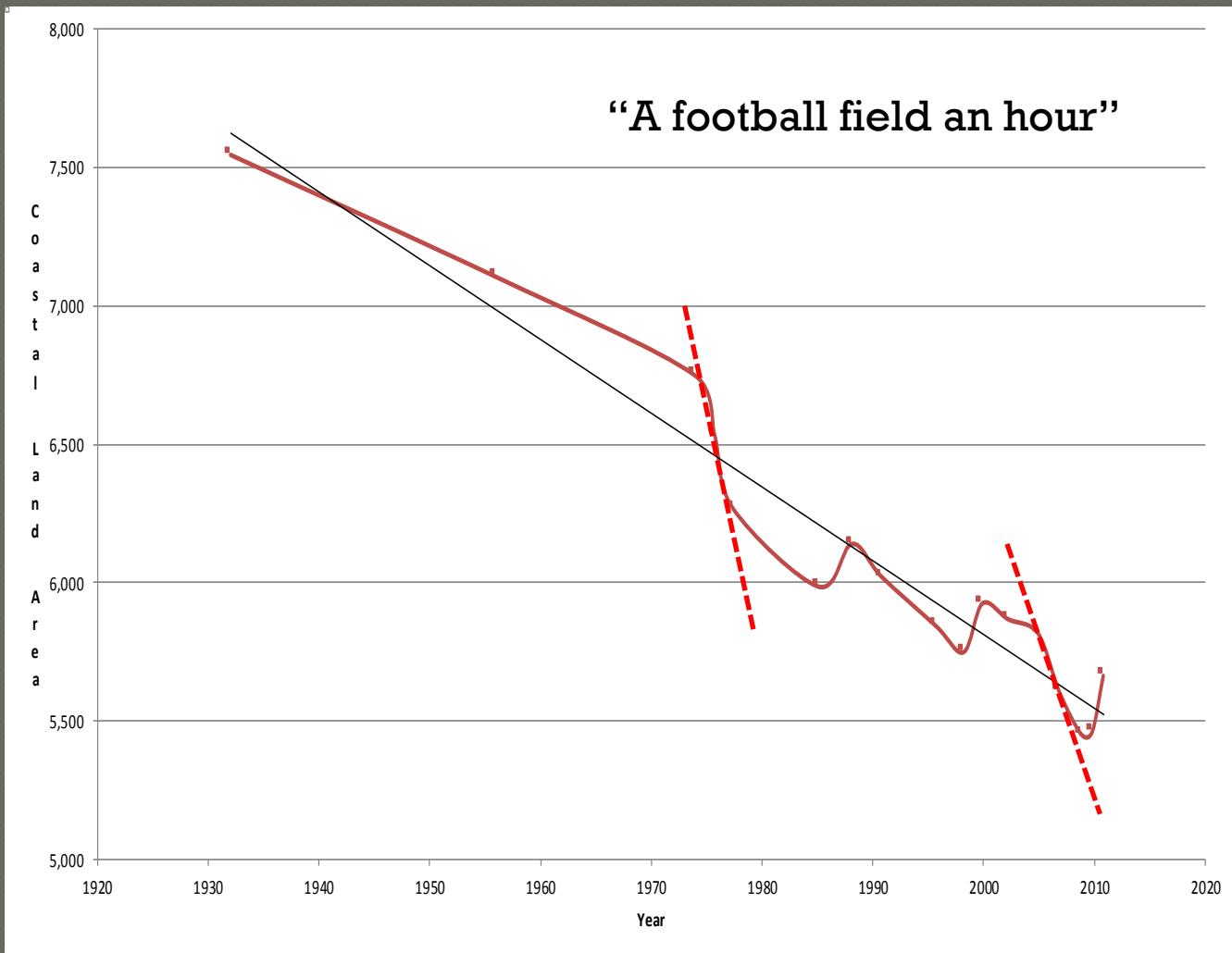


Oil & Gas Industry and Subsidence

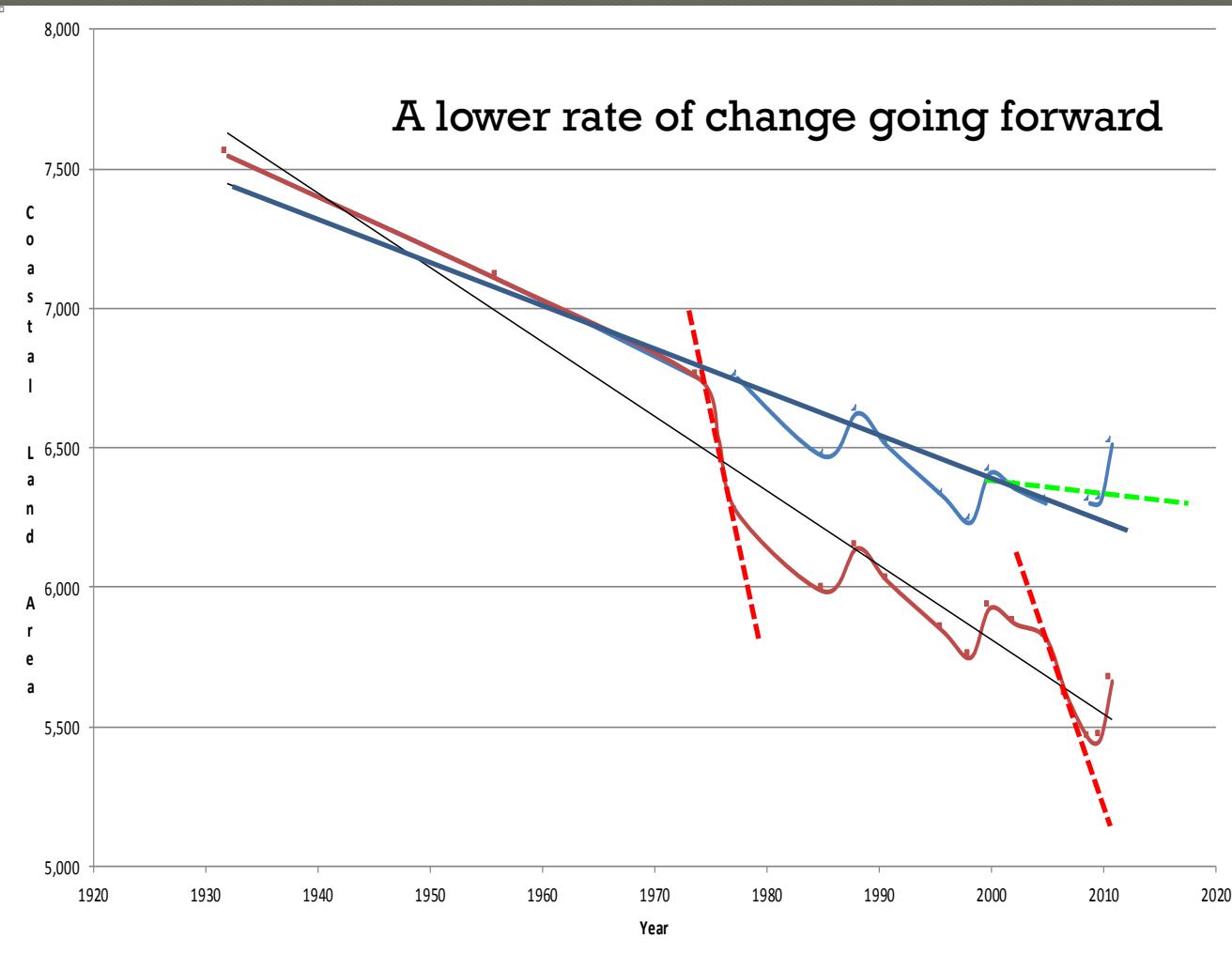


A Little Good News





A lower rate of change going forward



Questions?

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504-756-2003