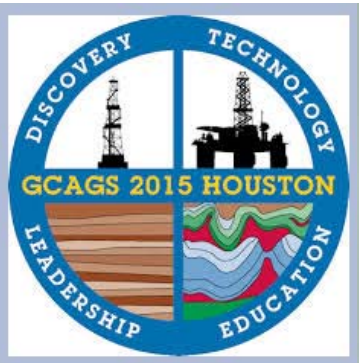


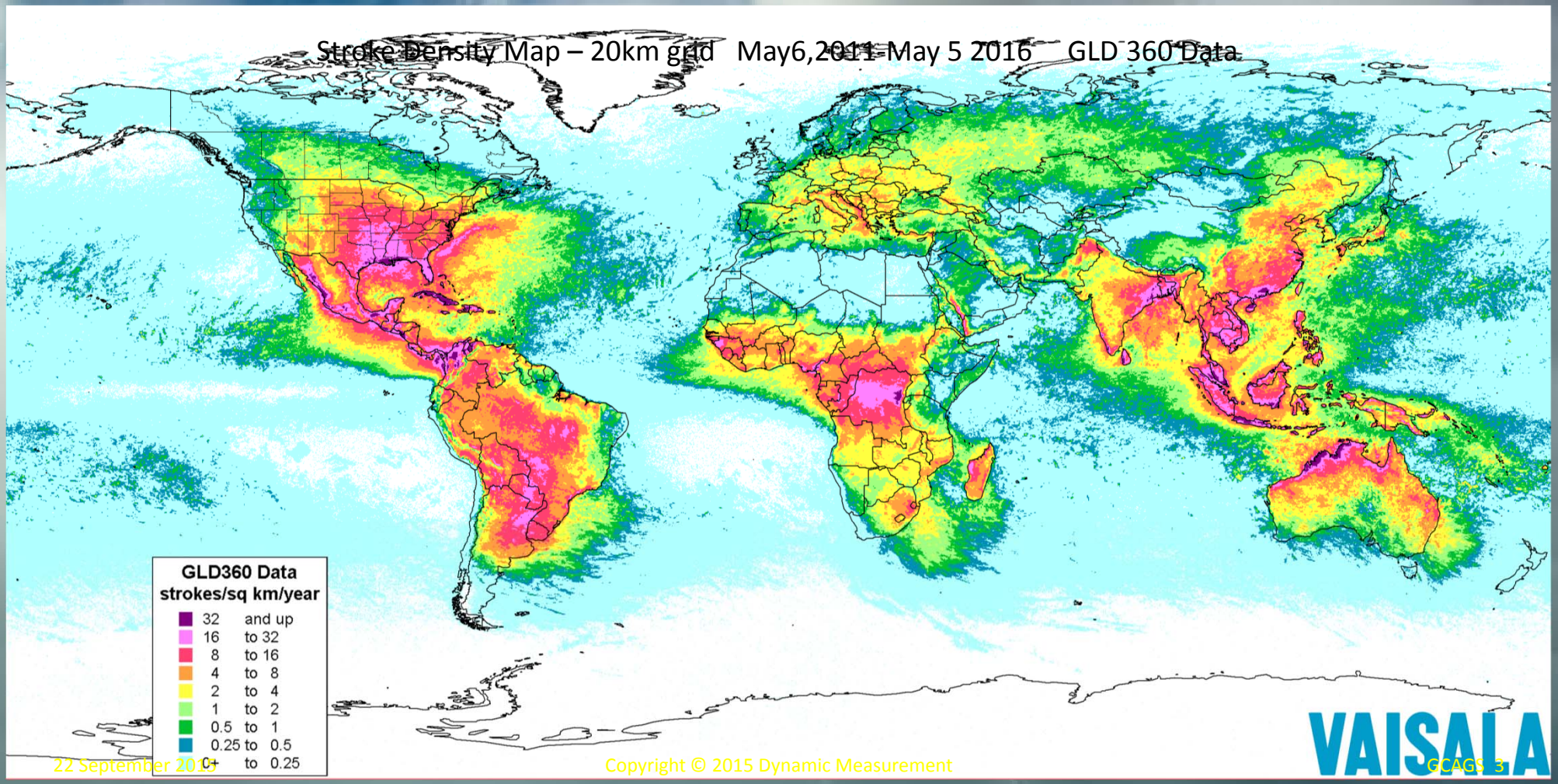
Analysis of the Goose Point area near Lacombe, LA, validates a new geophysical data type - natural sourced electromagnetism (NSEM™) for detection of lineaments associated with faults and sedimentary features.

Kathleen S. Haggar 1, Les R. Denham 1, Louis J. Berent 1

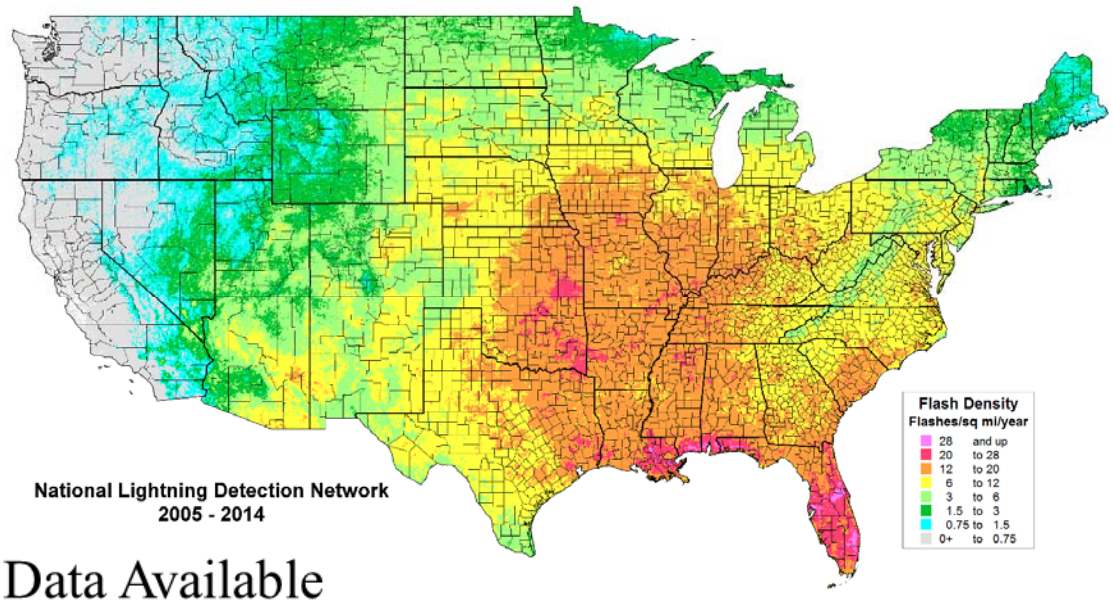
1 Dynamic Measurement, LLC, 211 Baker Road #382, Barker, TX 77431

Data and Theory

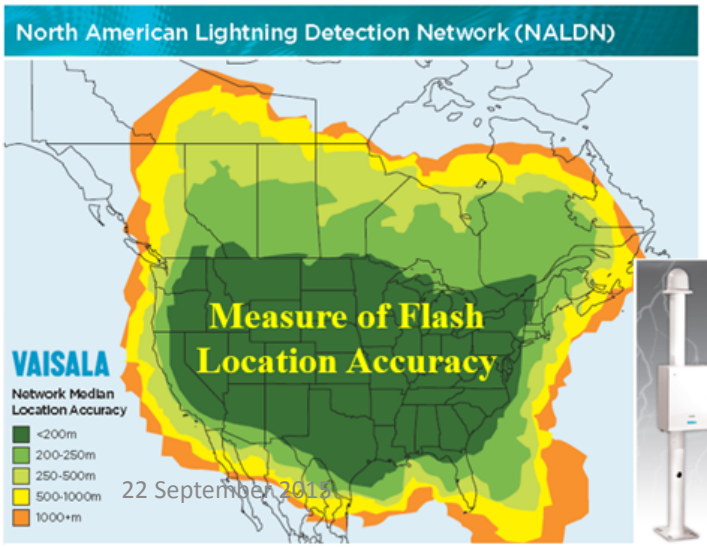
Lightning Occurs Everywhere

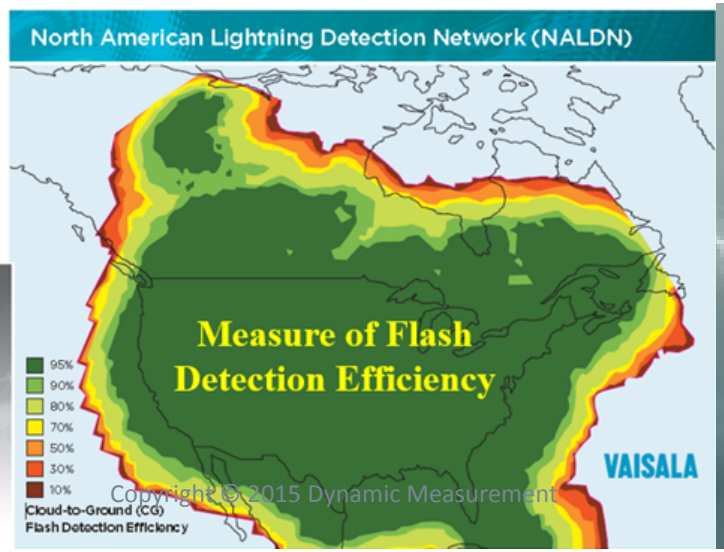


Houston To Miami receives 12 to 28 lighting strikes per square mile per year.



17 Years of NLDN Lightning Strike Data Available



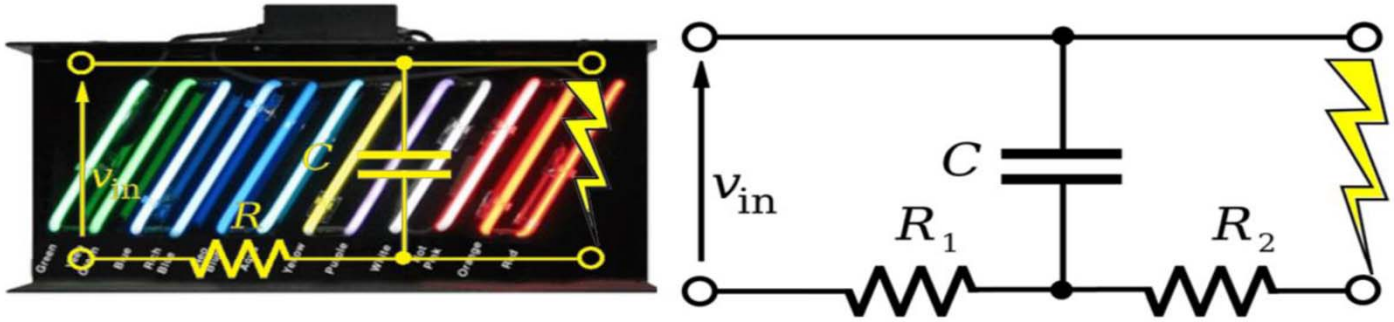


Network Median Location Accuracy Over most of US is 200 meters or less.

- Two conducting plates, the storm cloud and the earth
- Separated by an insulating dielectric - the atmosphere.
- Voltage, created by collision of ice within clouds
- Lightning bolts rebalance the charge between the plates.

See Lightning Think
DML
Dynamic Measurement LLC

Lightning Physics is analogous to Relaxation Oscillator Physics



- The atmospheric capacitor is nearly the same physics
- Just an additional resistance (R_2) limiting the current
- R_2 is the resistance between the lightning strike point and the bottom plate of the capacitor

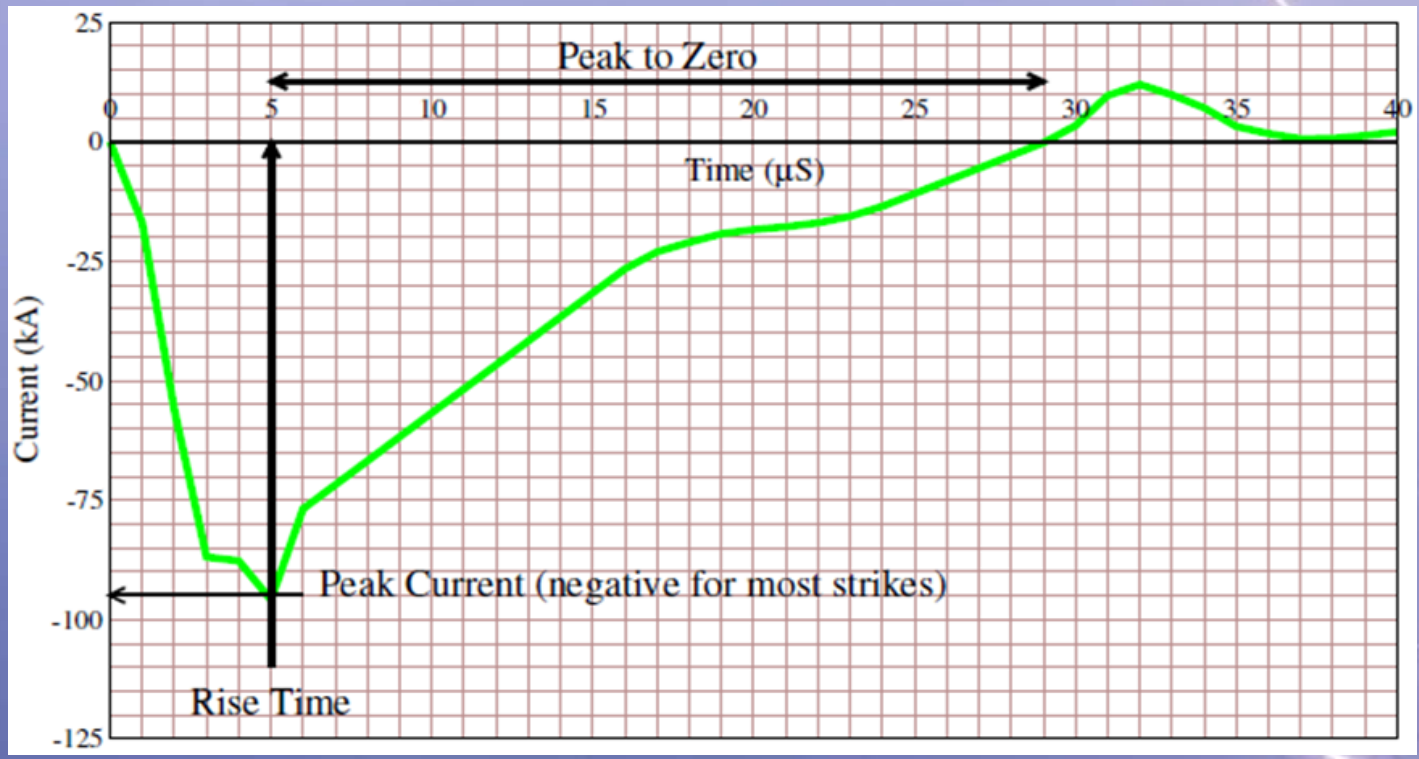
LIFE LANDMARK INNOVATION FORUM AND EXPO

Lightning

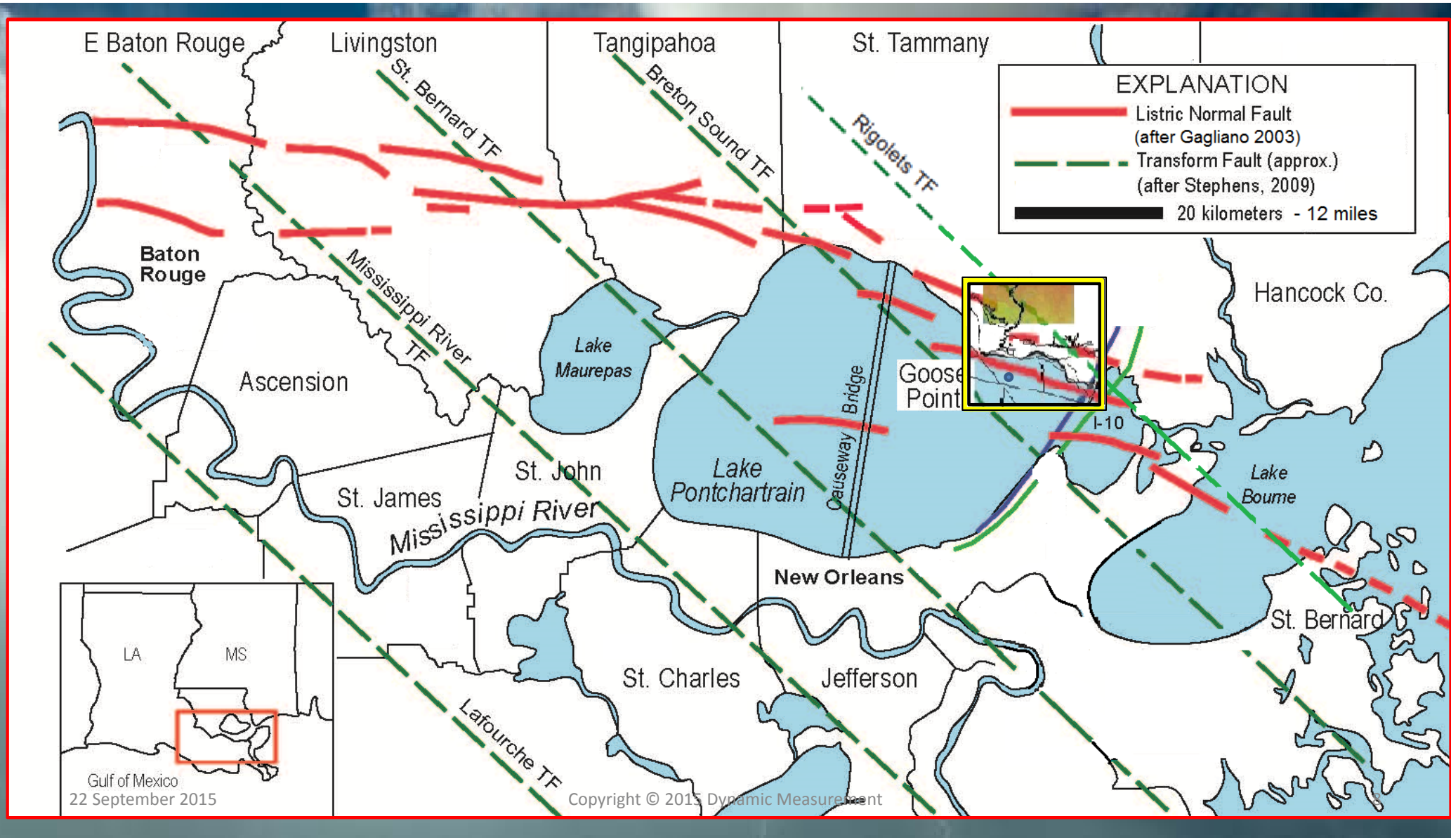
HALLIBURTON | Landmark

Lightning Measurements/Attributes, & Wave Form

- Location / Time and Duration / # of Sensors
- Rise Time
- Peak Current
- Peak to Zero
- Polarity
- Chi Squared
- Number of Sensors



Goose Point / Big Point Field


E Baton Rouge
Livingston
Tangipahoa
St. Tammany
St. Bernard TF
Breton Sound TF
Rigolets TF
EXPLANATION
Listric Normal Fault
(after Gagliano 2003)
Transform Fault (approx.)
(after Stephens, 2009)
20 kilometers - 12 miles
Baton Rouge
Mississippi River TF
Ascension
Lake Maurepas
Hancock Co.
Goose Point
Bridge
Causeway
I-10
Lake Pontchartrain
Lake Boume
St. John
St. James
Mississippi River
New Orleans
St. Bernard
St. Charles
Jefferson
Lafourche TF
LA
MS
Gulf of Mexico
22 September 2015
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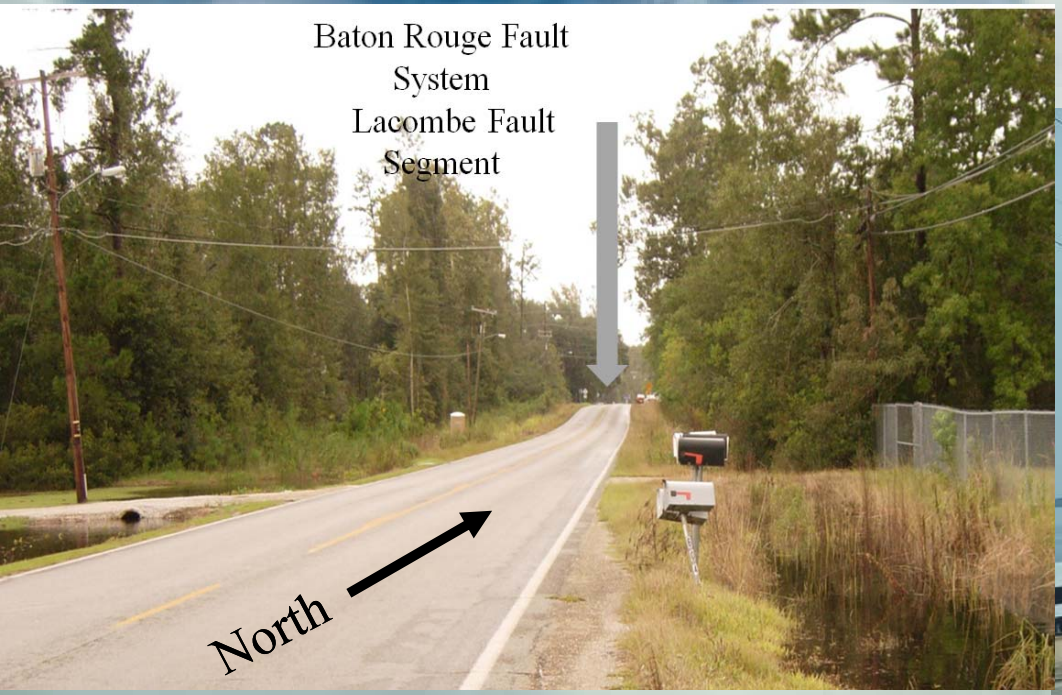
Typical Environmental Studies Often Lack a Framework for Integrating Diverse Data Sets

Fault offsets on roads or in the marsh
USGS sparker data
Oil and gas wells from state files
Water well logs
Dissertations and theses
Journals, government reports, gray literature

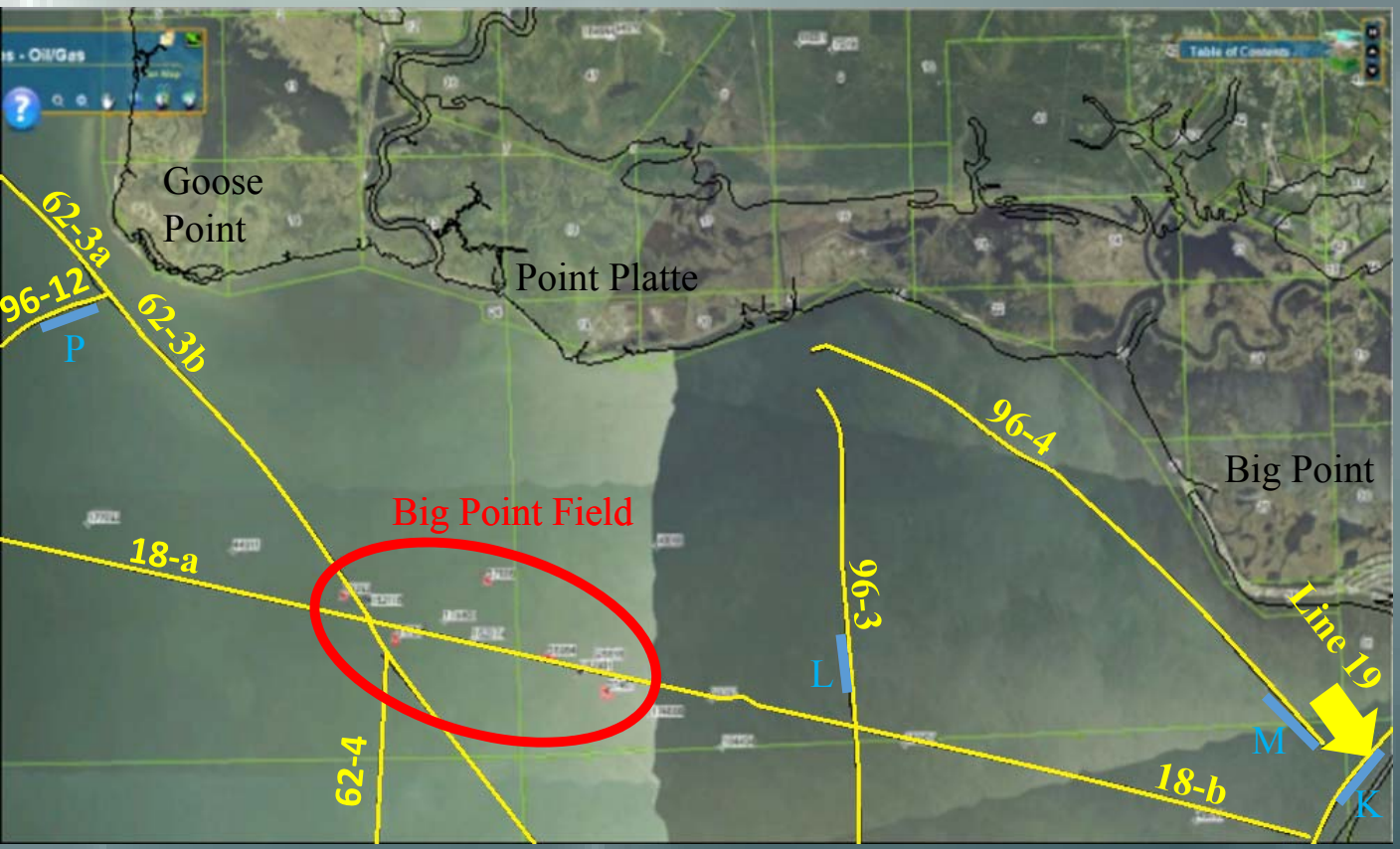
Baton Rouge Fault System Faults with Surface Expressions



Lacombe Fault Segment

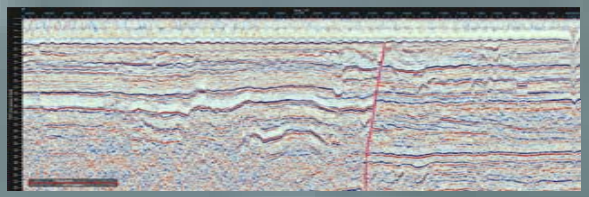
Goose Point Fault offsets Hwy 11 Bridge

USGS High Resolution Sparker Seismic - 1998

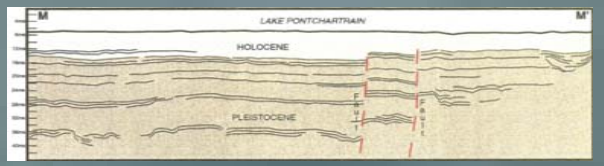


Sparker interpreted by L. J. Berent (— Roth, 1999 UNO Geology Thesis)

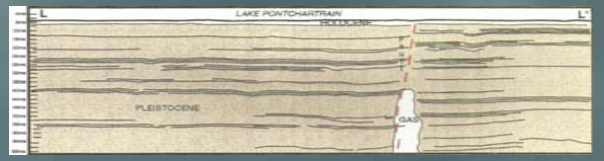
Line 19/K-K'



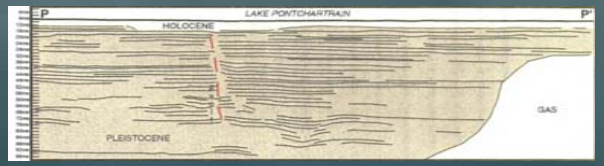
Line 96-4/M-M'

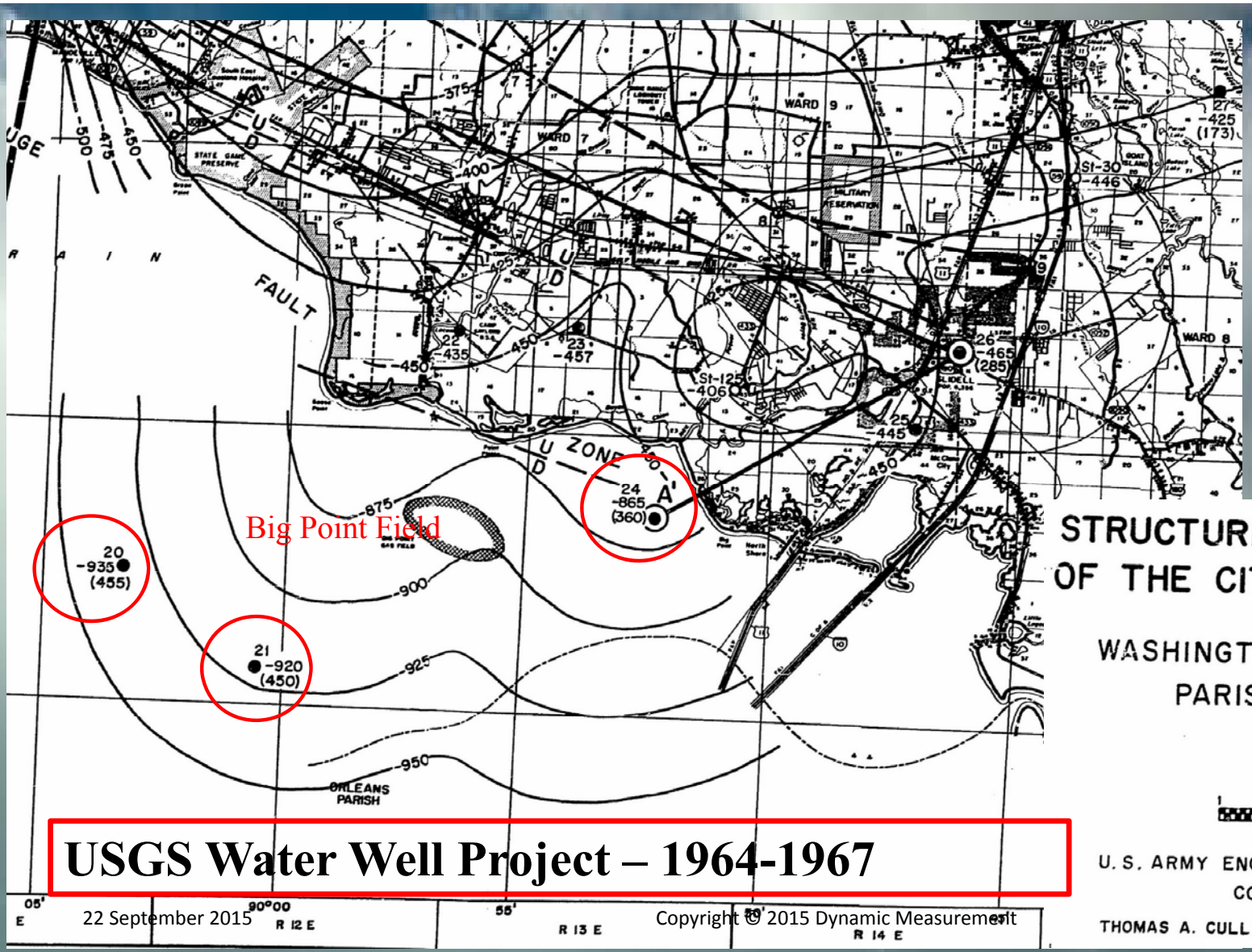


Line 96-3/L-L'



Line 96-12/P-P'





T. A. Cullinan's 1969 Tulane Dissertation of Big Point Field sparked new interest in fault interpretations.

STRUCTURE MAP ON THE BASE OF THE CITRONELLE FORMATION

WASHINGTON AND ST. TAMMANY PARISHES, LOUISIANA

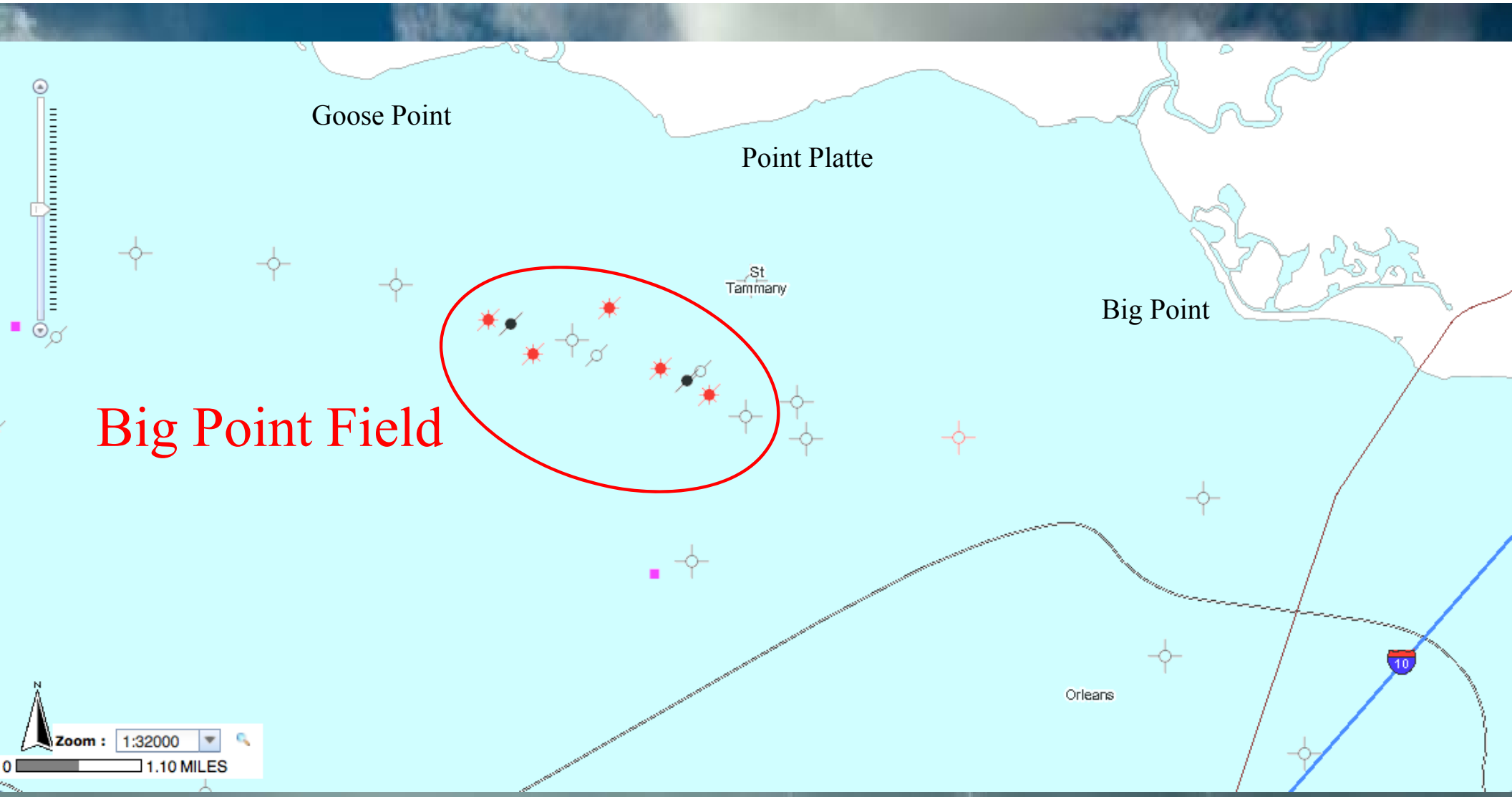
SCALE 1 0 1 2 3 4 MILES

U. S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

THOMAS A. CULLINAN

GCAGS 12
1969

USGS Water Well Project – 1964-1967



“The Geohazard Problem”

Surface faults can be avoided/designed for if they are recognized.

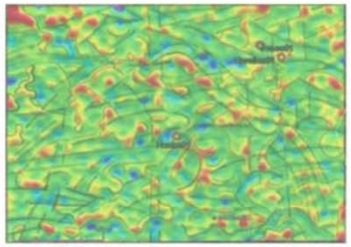
Engineers do not design for unknown hazards – not imaged by geotech.

NSEM provides connectivity to diverse data sets and may offer cost effective insights on areas that need additional data.

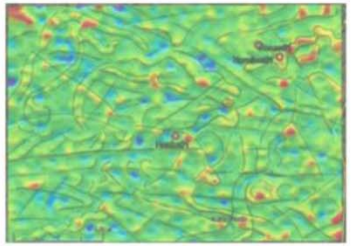
Lightning Attribute Maps provide insight into Rock/Sediment Properties

Attributes Calculated or Displayed with DecisionSpace®

Surface Resistivity:



Peak-to-Zero:



Seismic Attributes

- Instantaneous
- Wavelet
- Geometrical
- Reflective
- Curvature
- Dip
- Semblance/Coherence
- AVO / AVA
- Derivatives

Lightning Map Attributes

- Rise-Time
- Peak Current
- Peak-to-Zero
- Total Wavelet Time
- Symmetry
- Density
- Rise-Time-Rate
- Temporal Versions
- Tidal Gravity

Lighting Volume Attributes

- Resistivity
- Instantaneous Resistivity
- Curvature Resistivity
- Permittivity
- Wavelet Permittivity
- Dip Permittivity
- Temporal Versions:
- Before Event
- After Event

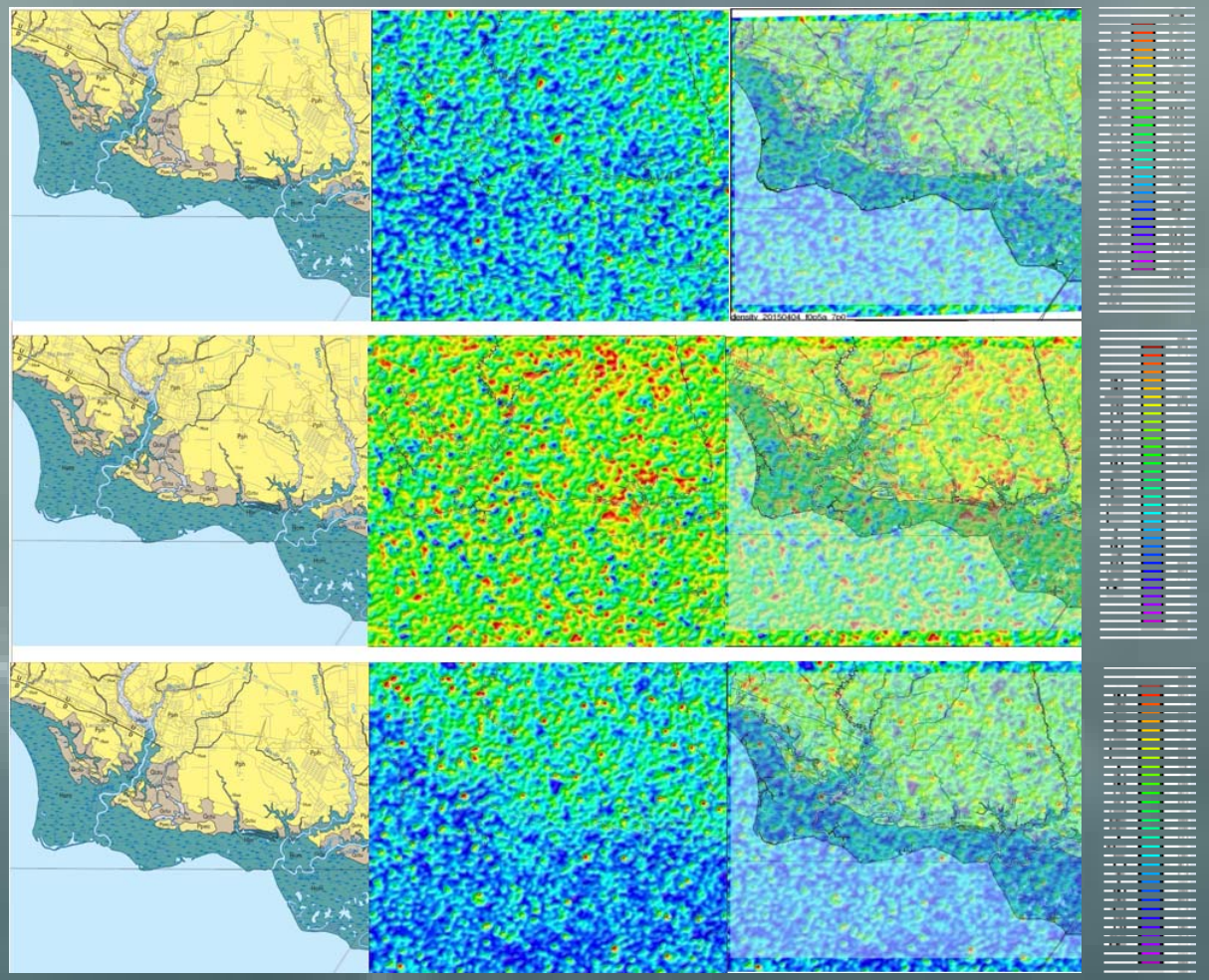
LIFE LANDMARK INNOVATION FORUM AND EXPO

7

HALLIBURTON | Landmark

There are more lightning attributes than seismic

Google Earth Image
Study Area in Yellow

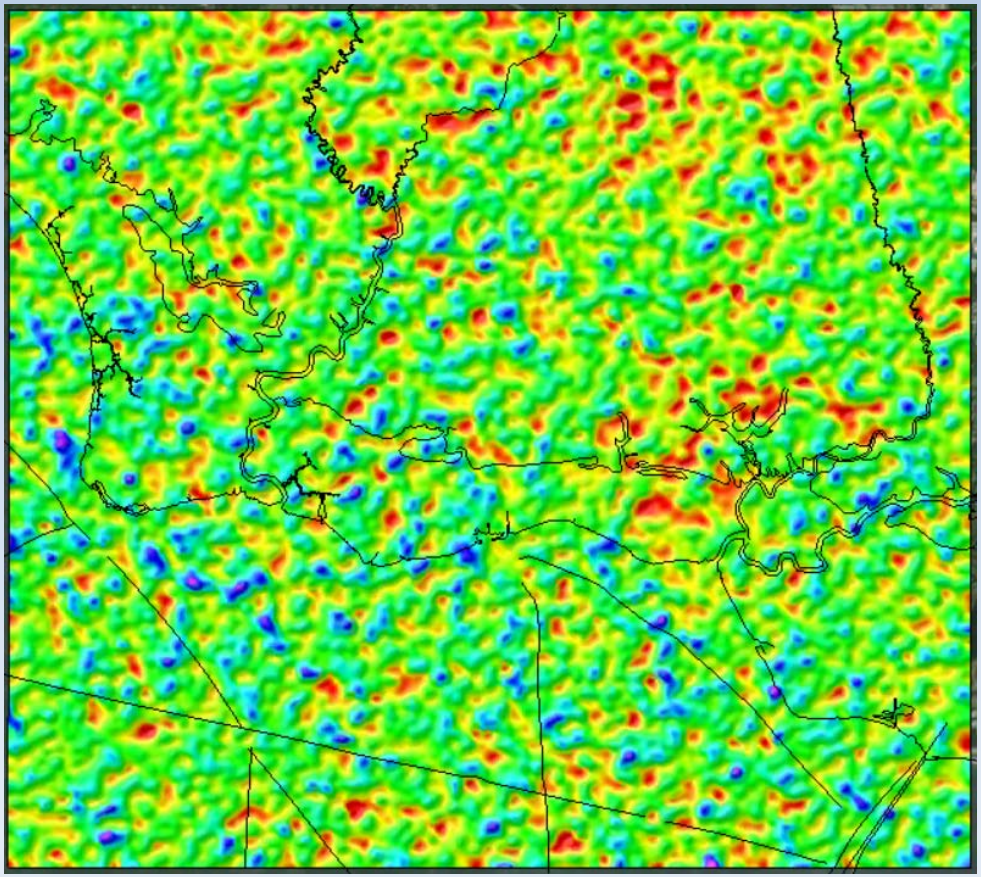


Geologic Map
McCulloh (2004)

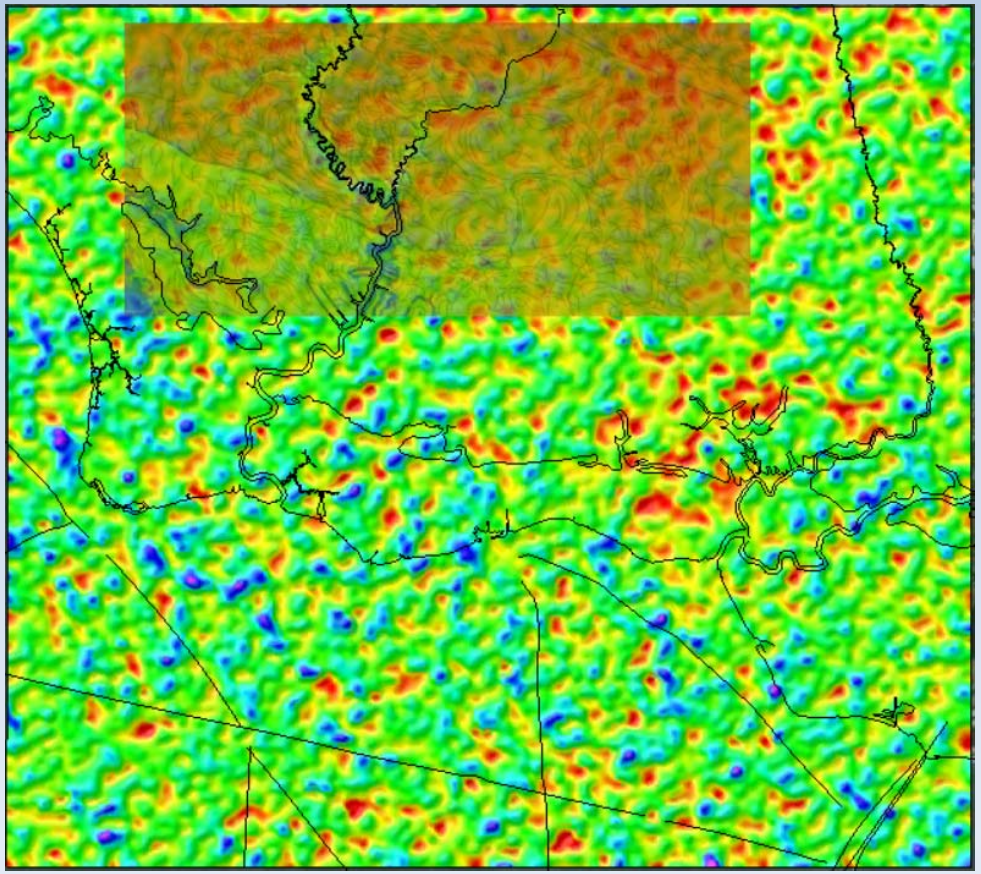
Rate of Rise Time
Rise Time
Strike Density

Attribute Transparency
over Geology Map

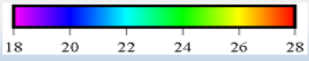
Rise Time over Entire Study Area 110 sq. mi.

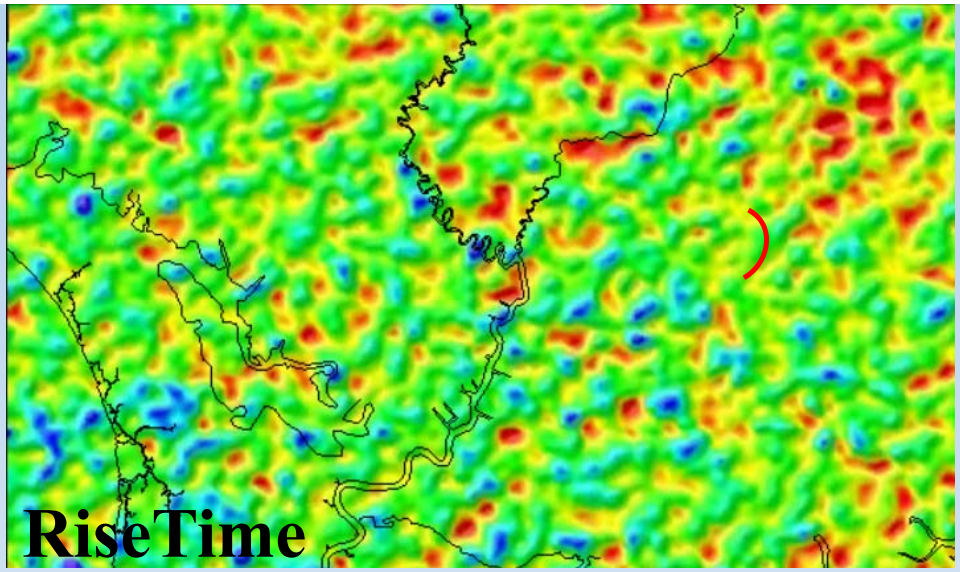


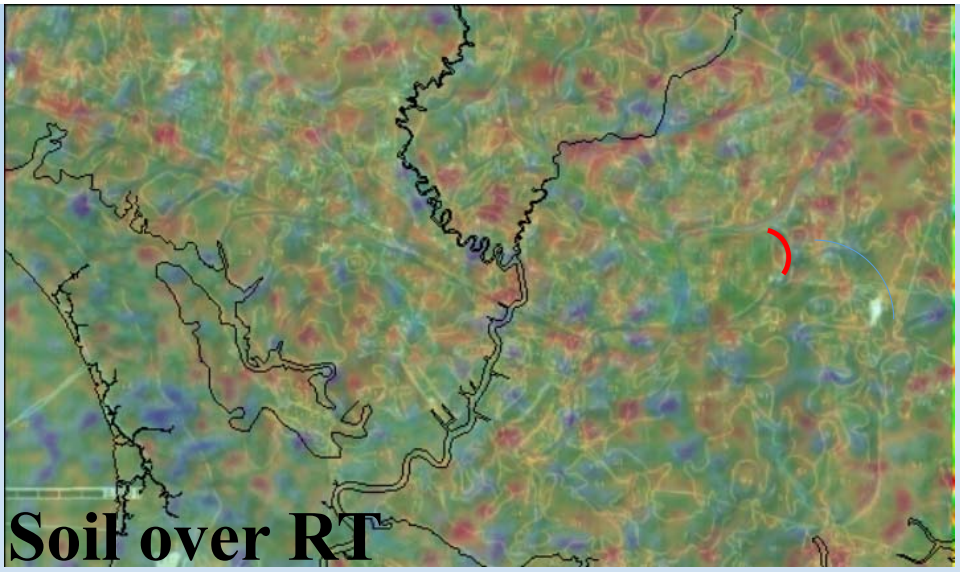
Rise Time with Focus Box highlighted with LIDAR

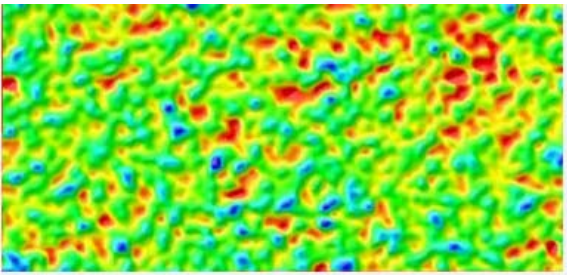
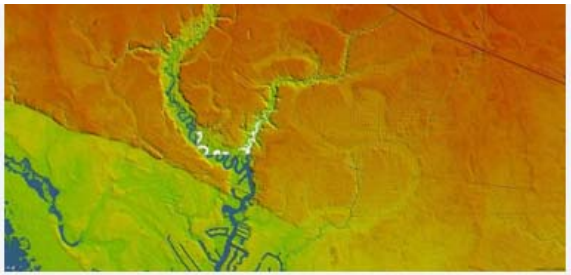
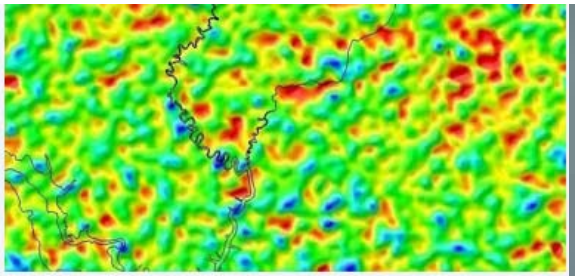
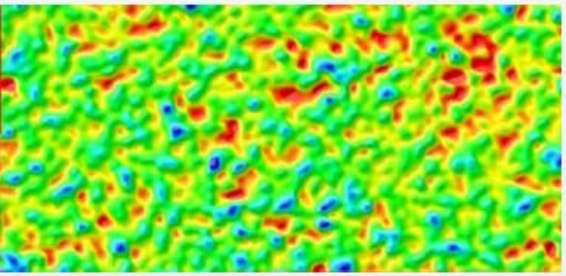
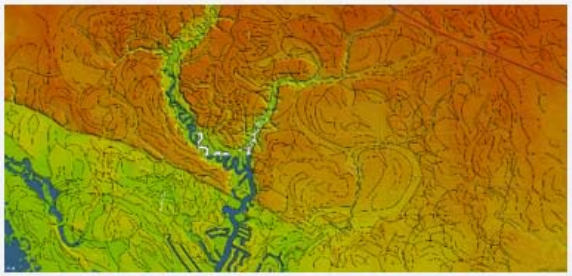
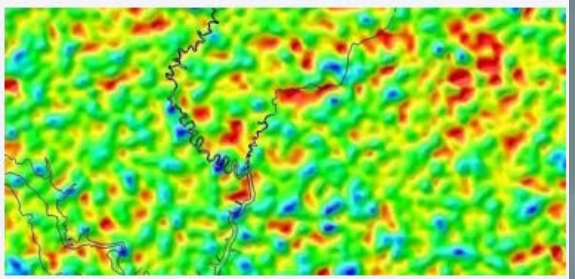
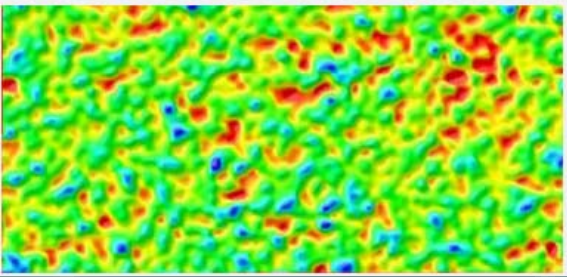
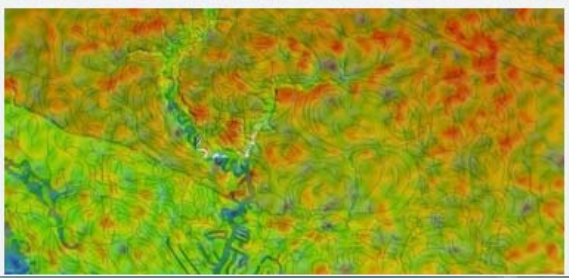
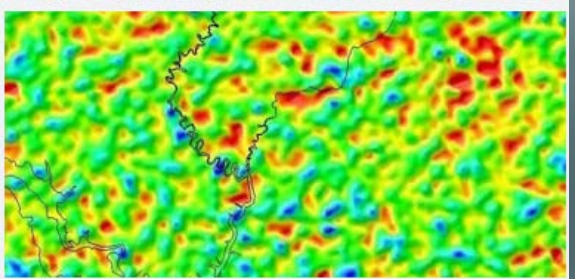


Rise-Time scale





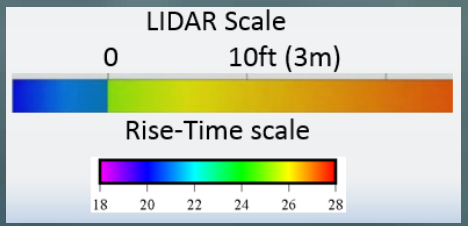


Rise Time Attribute

LIDAR
Annotated LIDAR
Rise Time transparency
over
Annotated LIDAR

Rise Time Attribute
with stream Channels

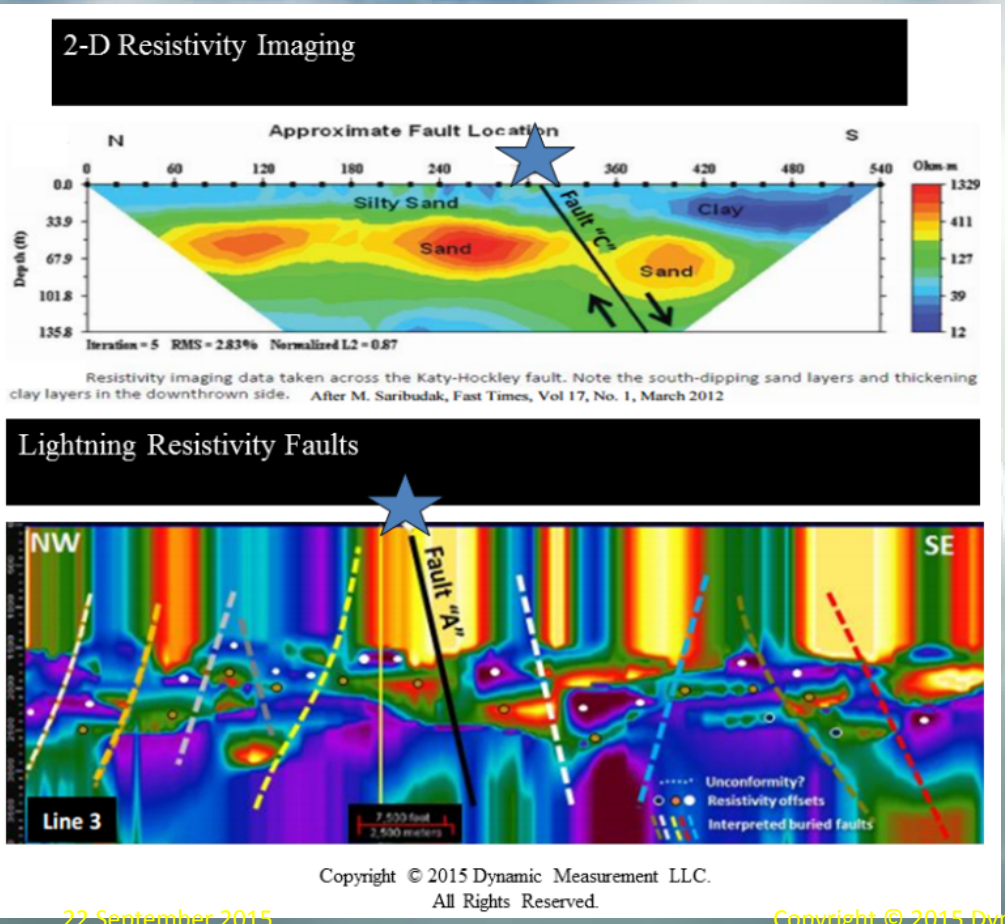


Lightning Rock Property Volumes

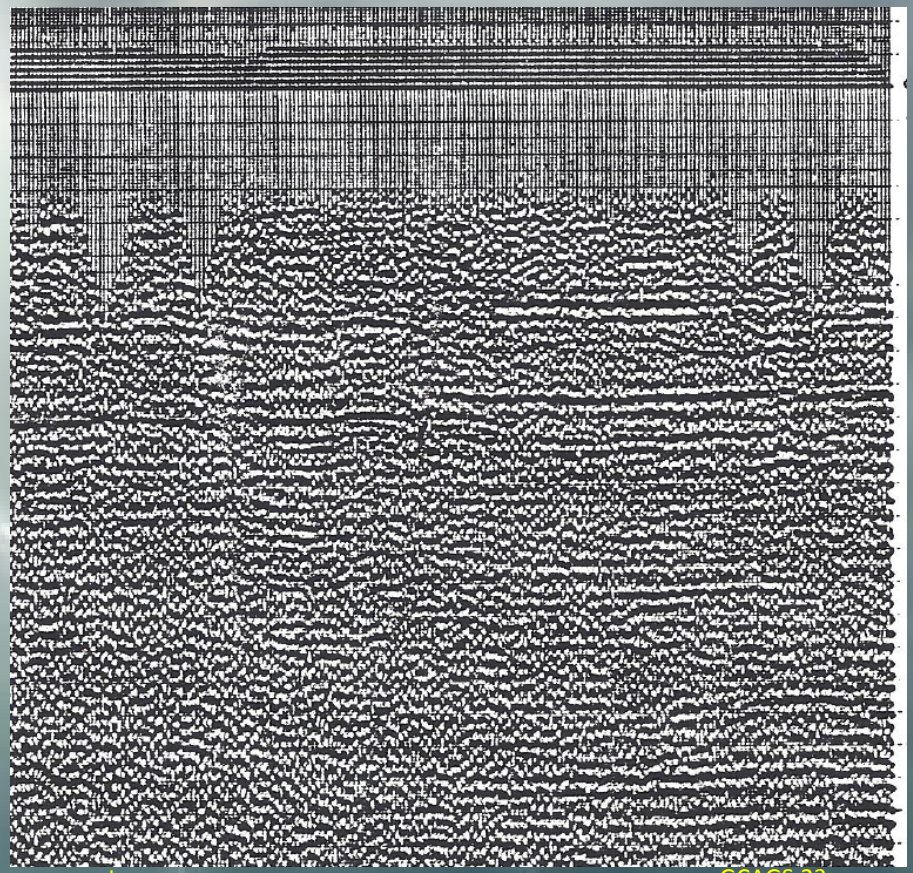
Apparent Resistivity and Permittivity Volumes, provide a framework for integrating and interpreting multidisciplinary data sets.

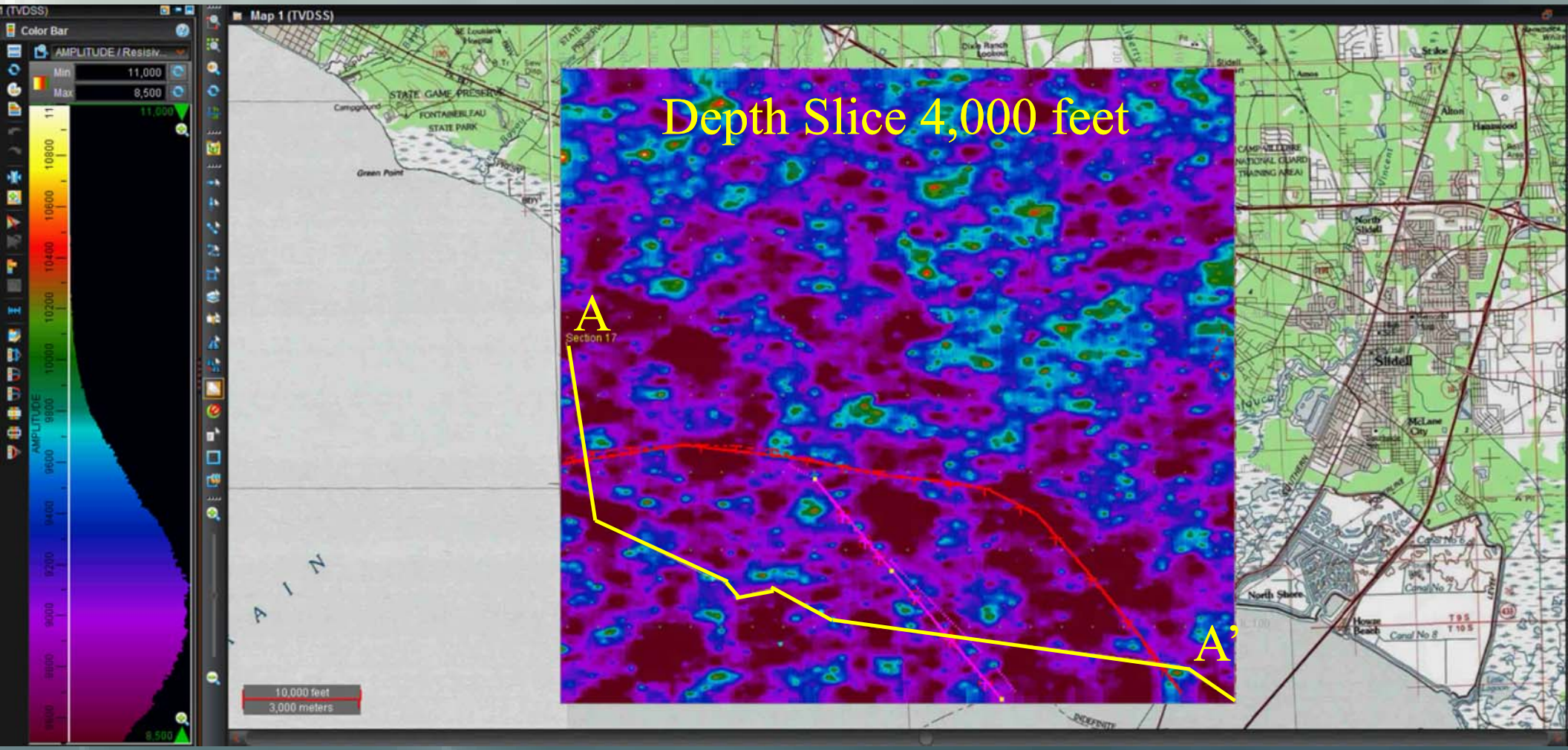
Goose Point / Big Point Field Area Lightning Attribute Volumes- Resistivity Data

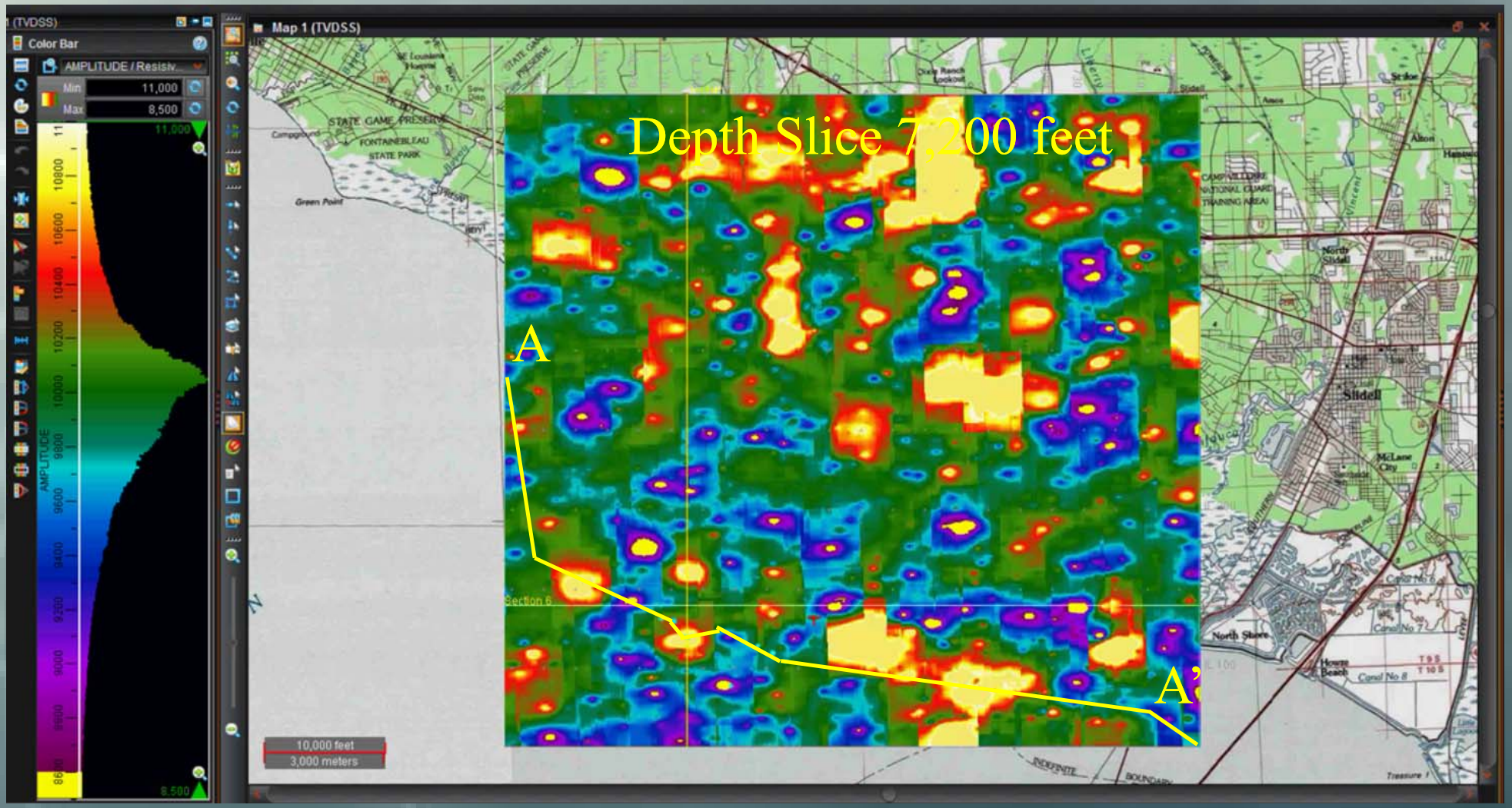
Conventional Resistivity Profile
NSEM Profile

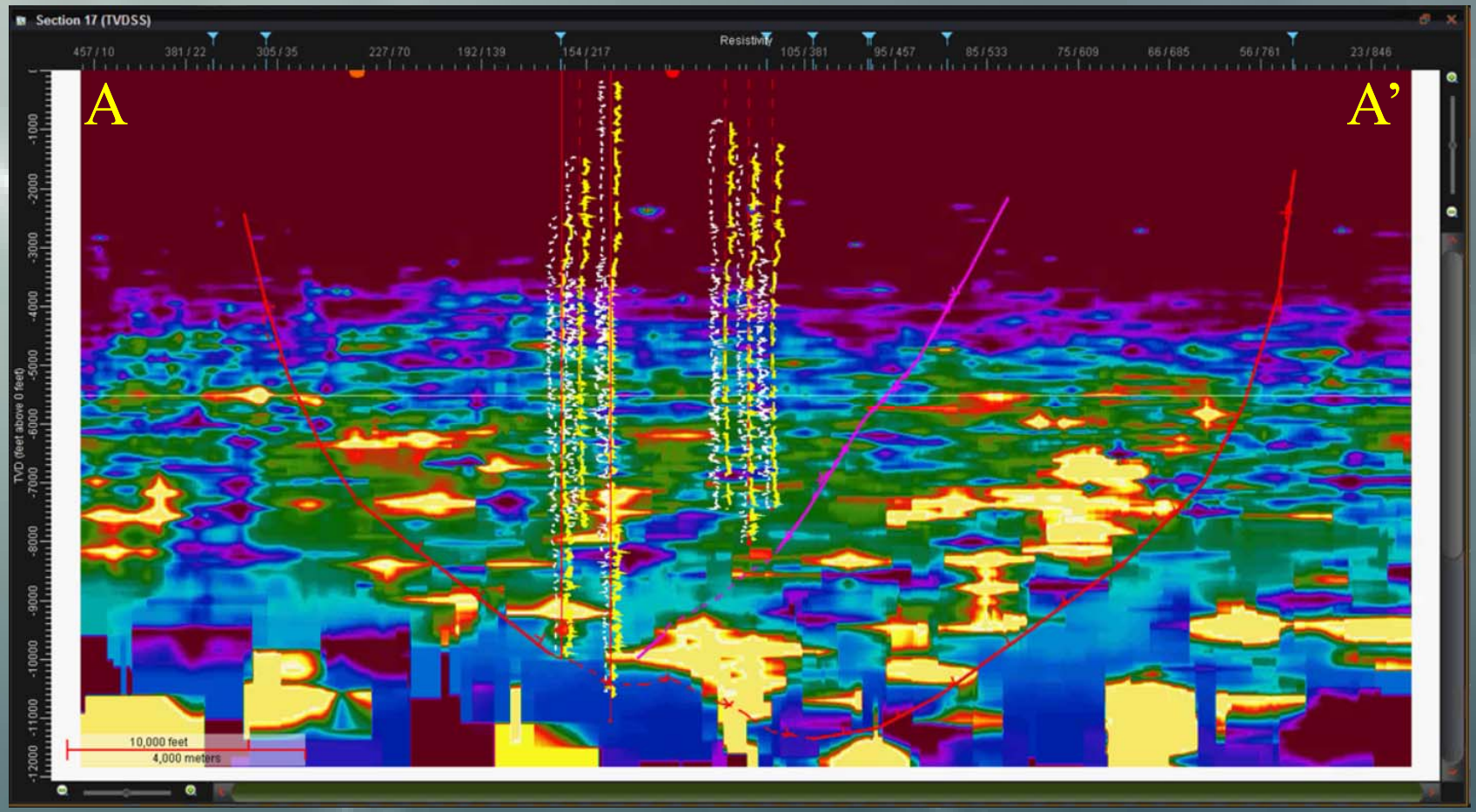


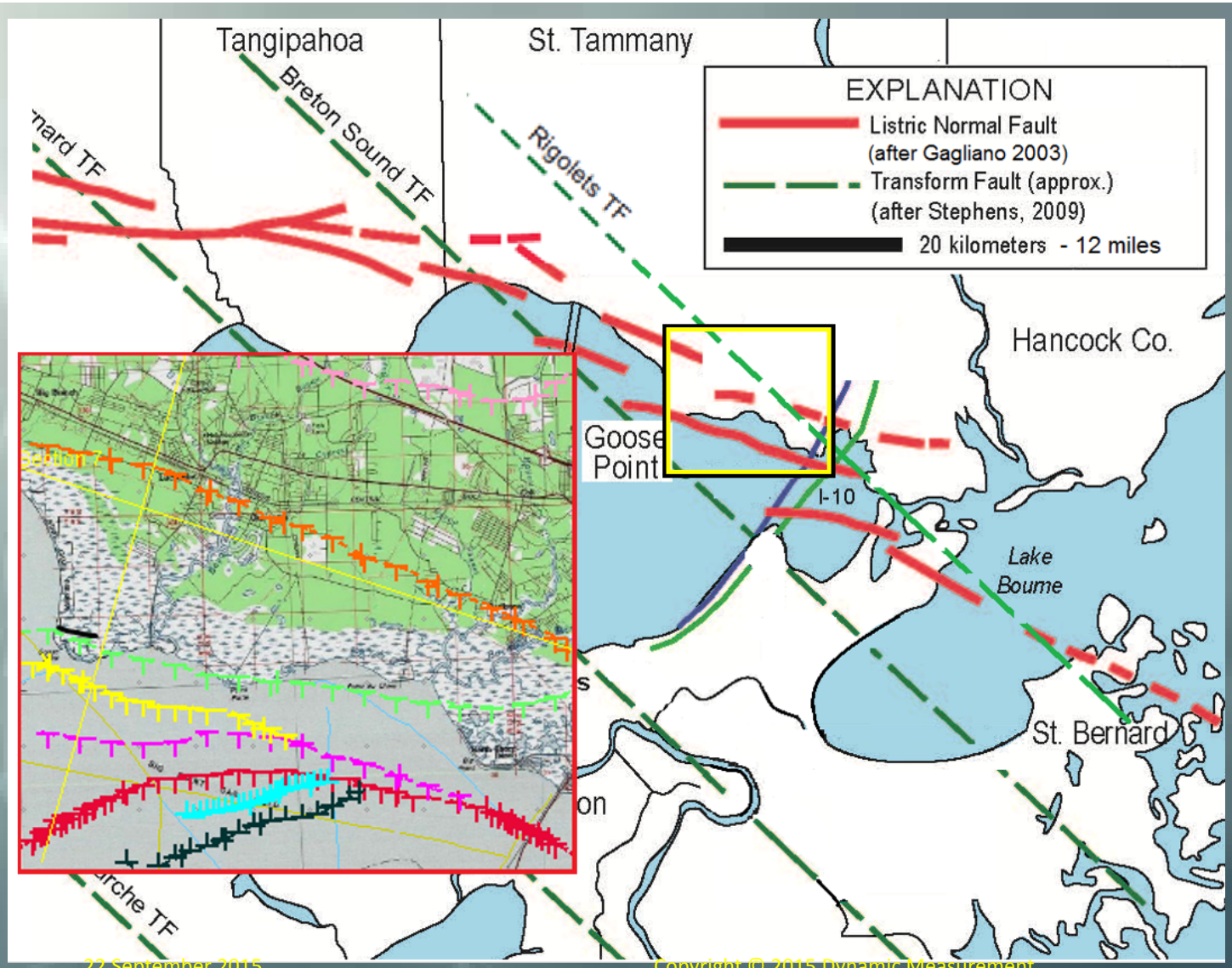
1971 Seismic Line





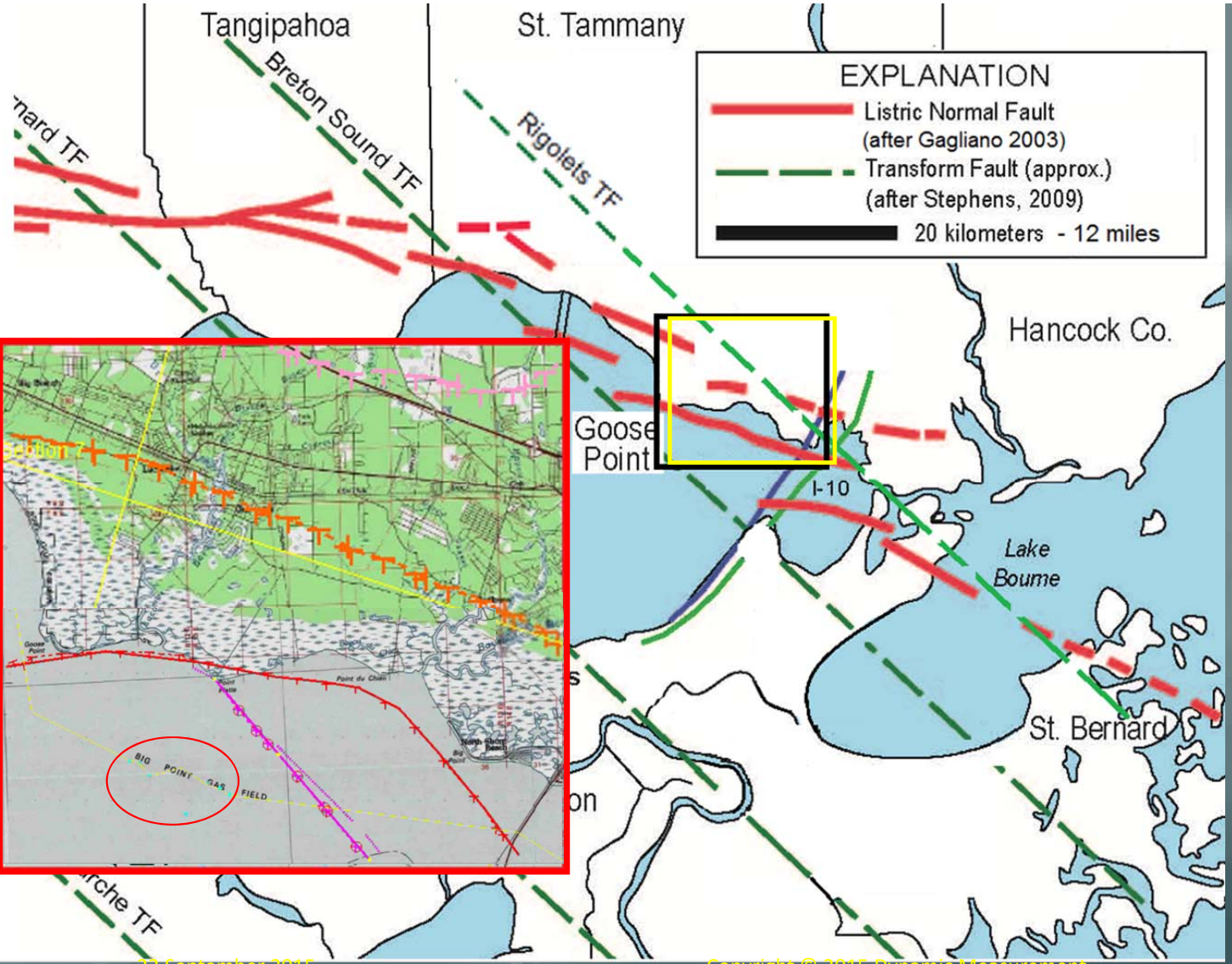






Fault interpretation using just using LIDAR, sparker, bridge offsets and NSEM - lightning data

No well data in this interp.



Fault Interpretation with Sparker LIDAR/Soils Limited Well Data and NSEM with new processing algorithm

Conclusion

Lightning provides connectivity between datasets and within a regional geologic framework

Rock property attributes relate to LIDAR and Soils

Resistivity Volumes provide insights into stratigraphy, structure, and rock properties.

Thank You!

Lightning - A Shockingly Powerful Exploration Technology