



Lightning; A Shockingly Unconventional Way to Conduct Exploration

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Outline

Lightning, and why it is tracked, stacked & mapped!

Natural Sourced Electromagnetism (NSEM) – a new geophysical data type.

Examples of using NSEM

Time-Line of New Geophysical Data Types



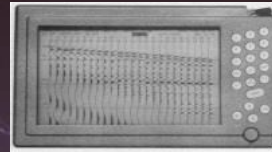
1752



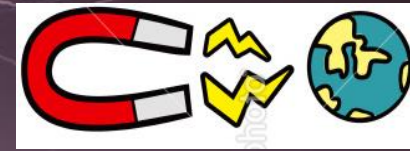
1833



1920s



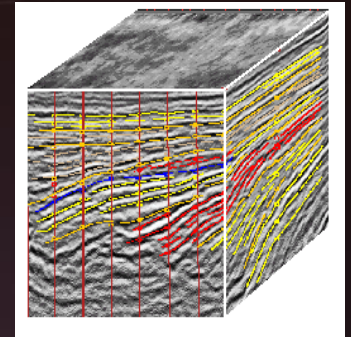
1950s



1960s/70s



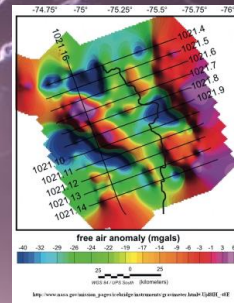
1974



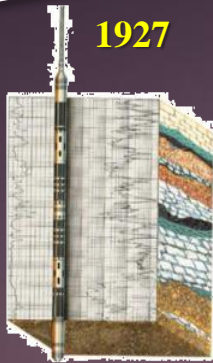
1931



1936



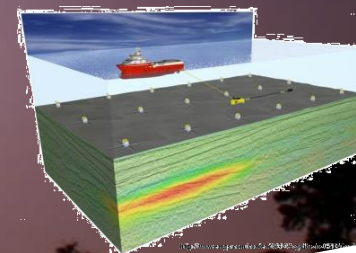
1927



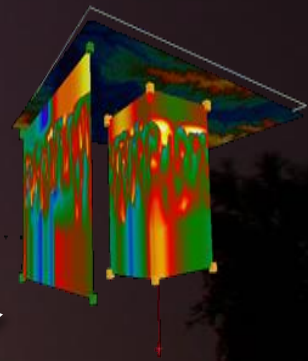
2008



1997



2015

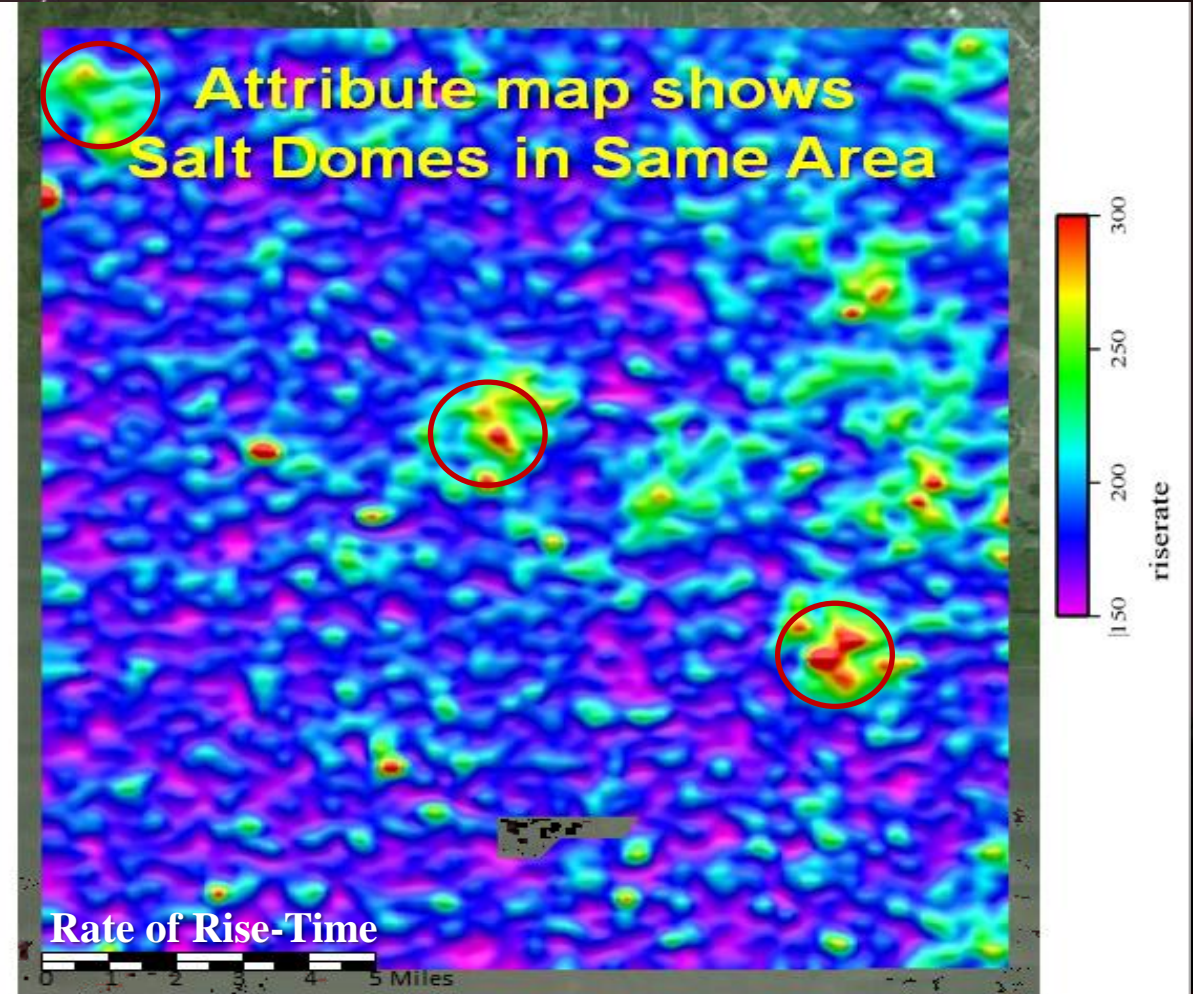
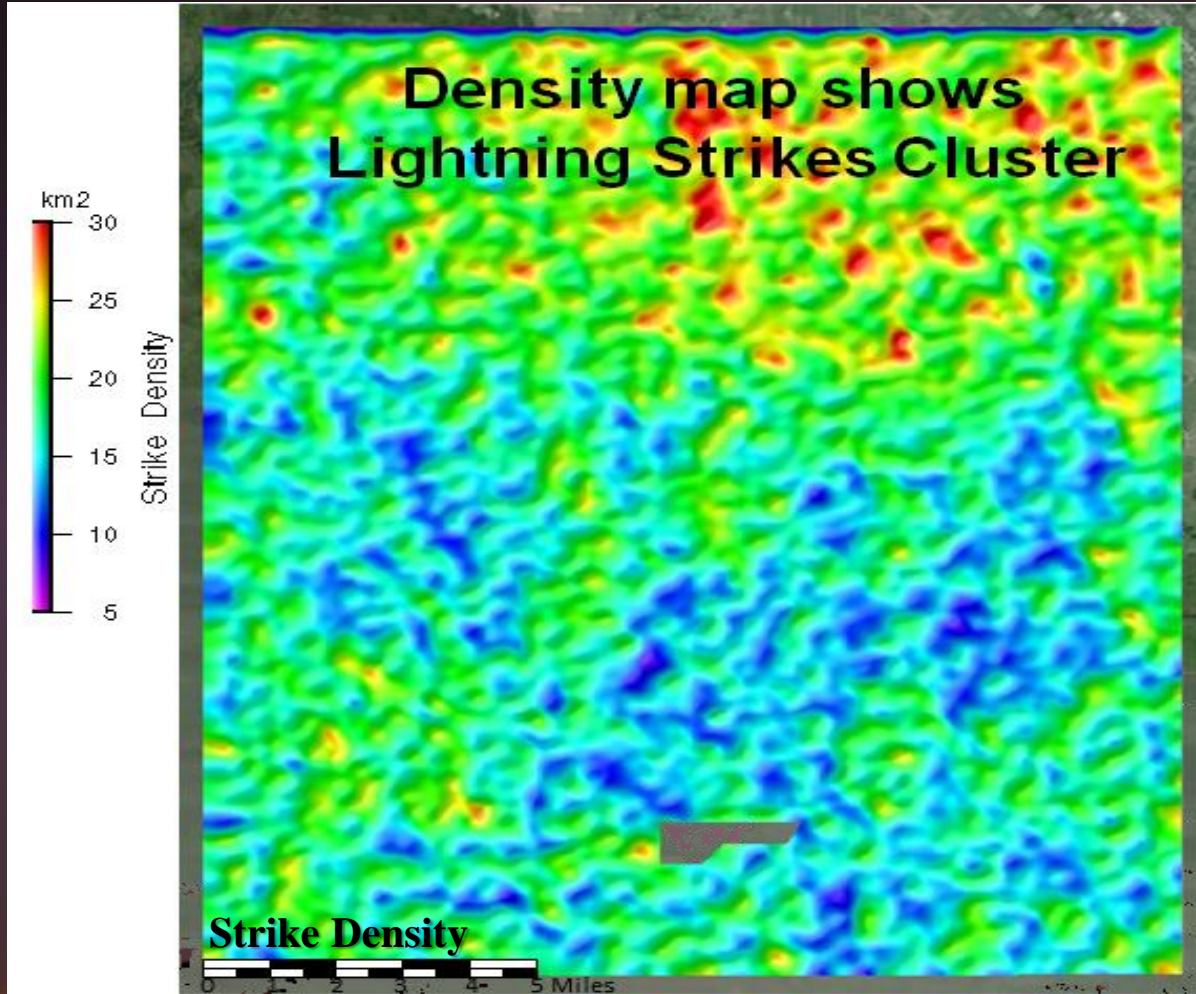


Each data type triggered a step change in new revenues and cost avoidance for upstream oil and gas companies.

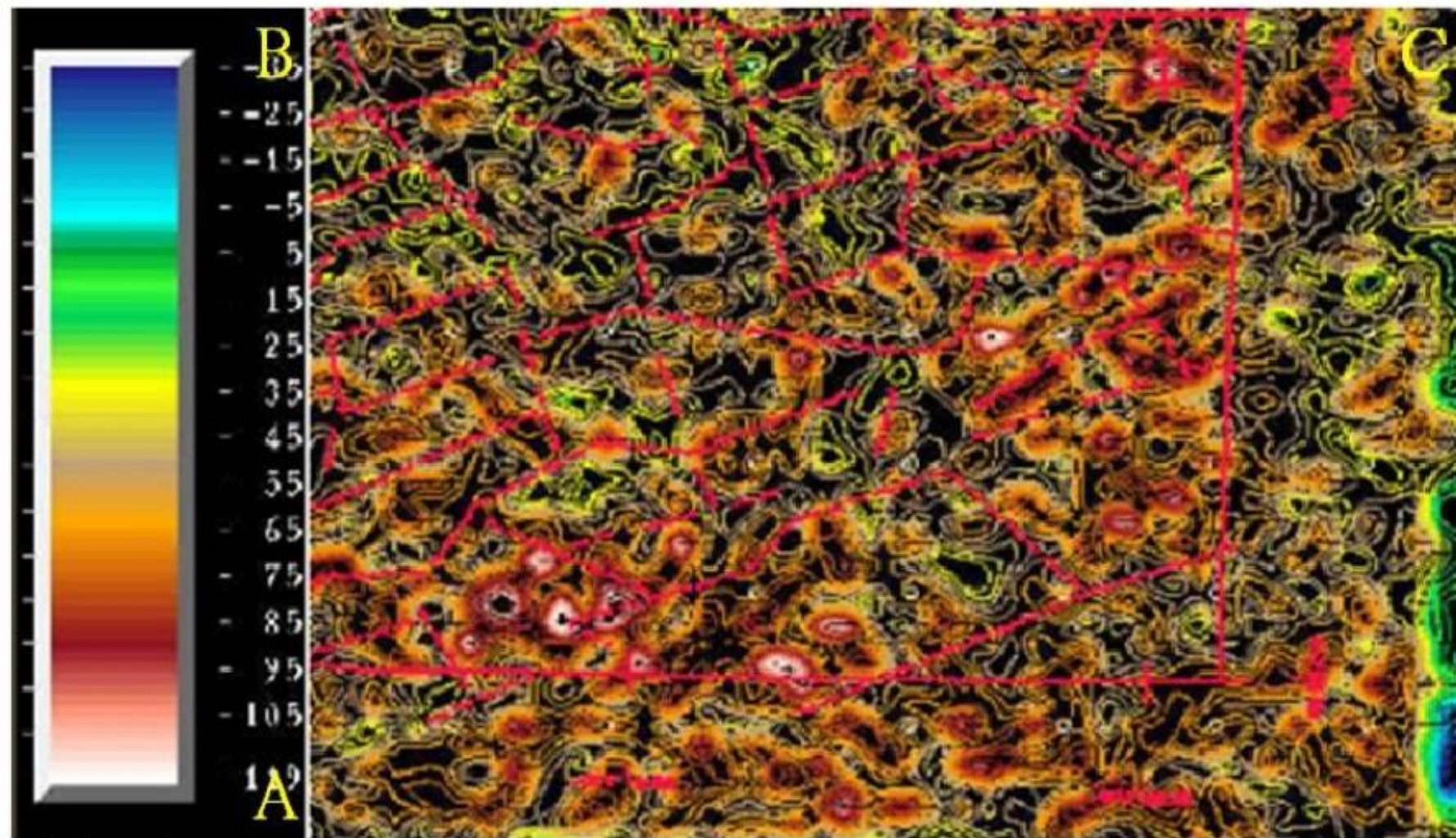
Can Lightning Hit the Same Place Twice?



NSEM Correlates To Geology: Iberia Parish, LA Salt Domes



Enlightening Aeromagnetics – Steuben County, NY



Lightning Density Map and NewMag® Interpretation

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19 Jan 2016

Why is lightning recorded?

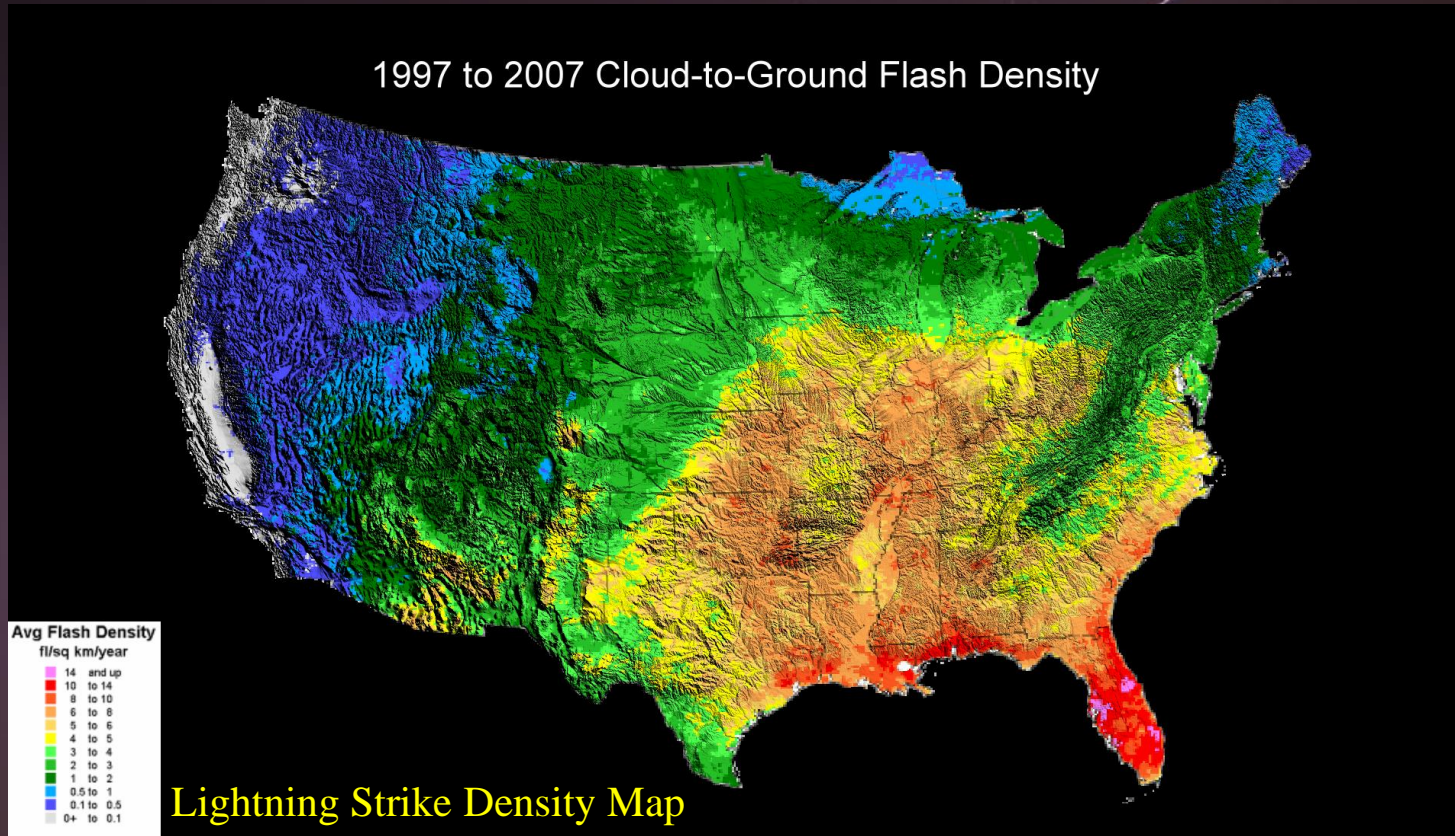
Early Storm Warning - Safety - Insurance - Meteorology



Dead Cattle along a fence



25 Million Annual U.S. Lightning Strikes 17 Year Database, Rich Database to Mine

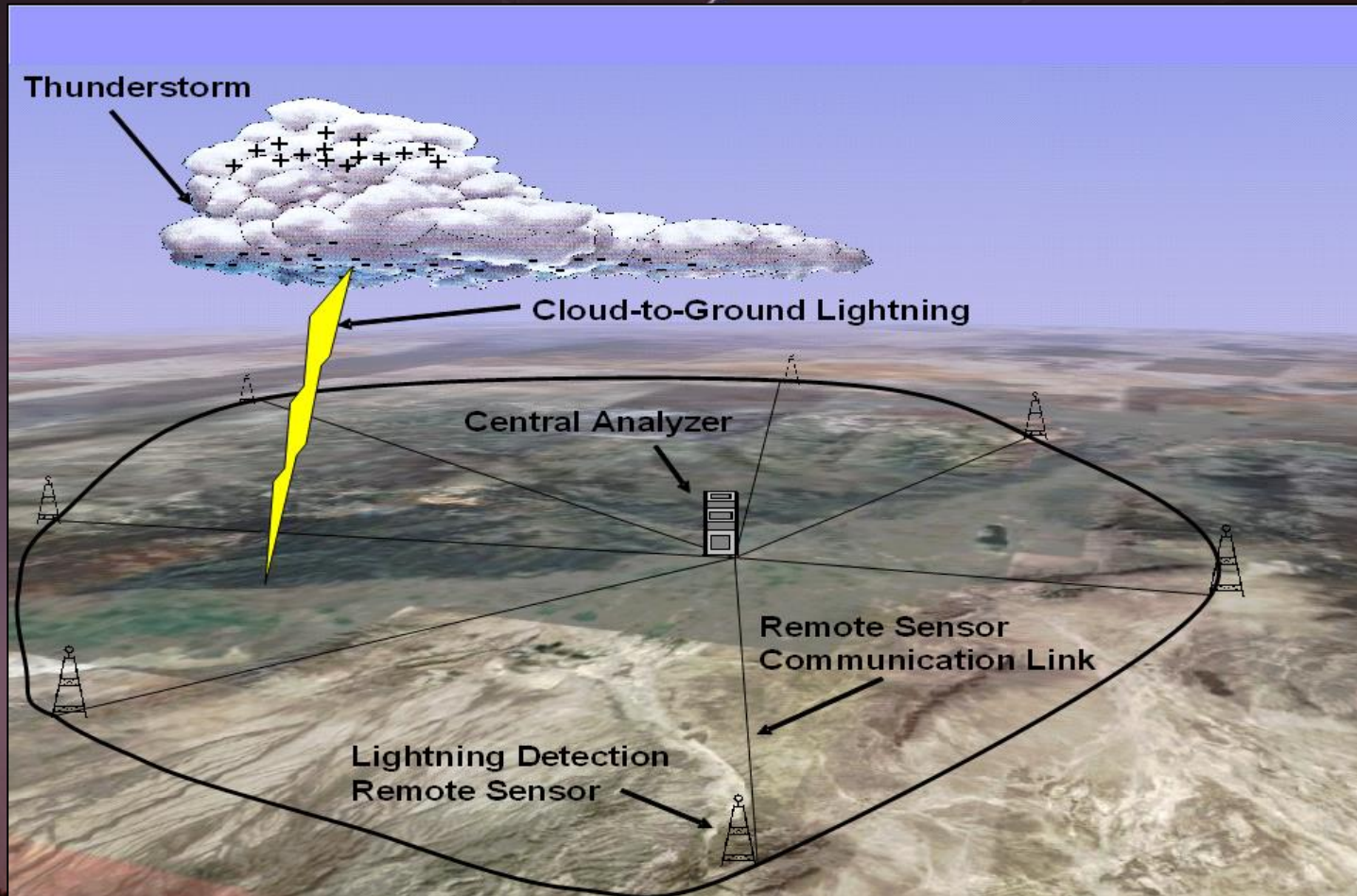
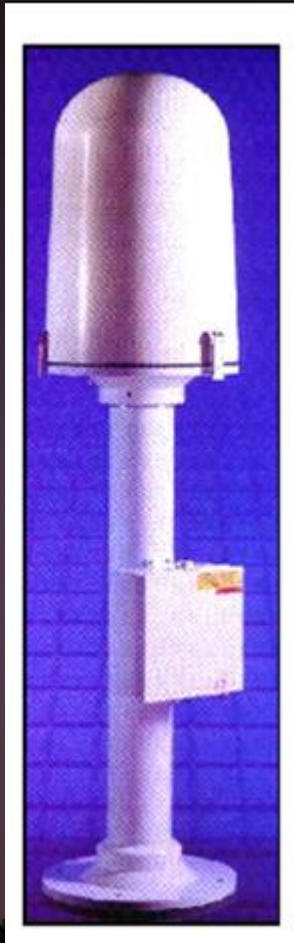


Lightning strikes - uneven distribution but not random!

Lightning strike density regionally controlled by meteorology, and locally controlled by terralevis (shallow earth) currents.

How is Lightning Data Collected?

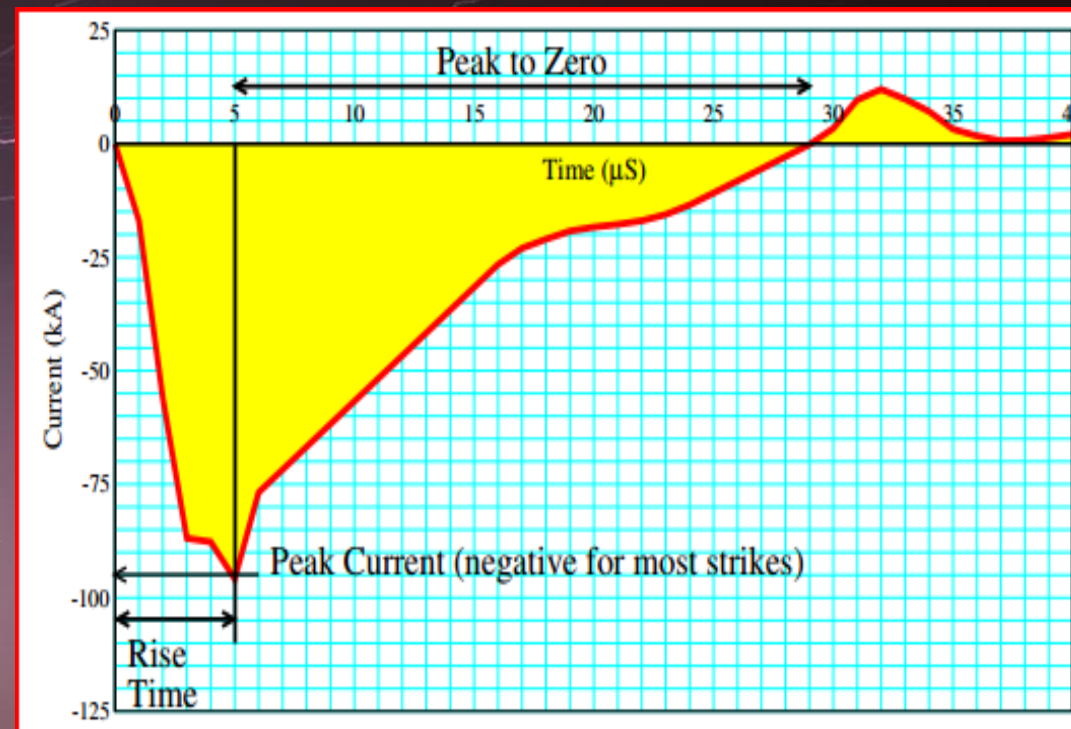
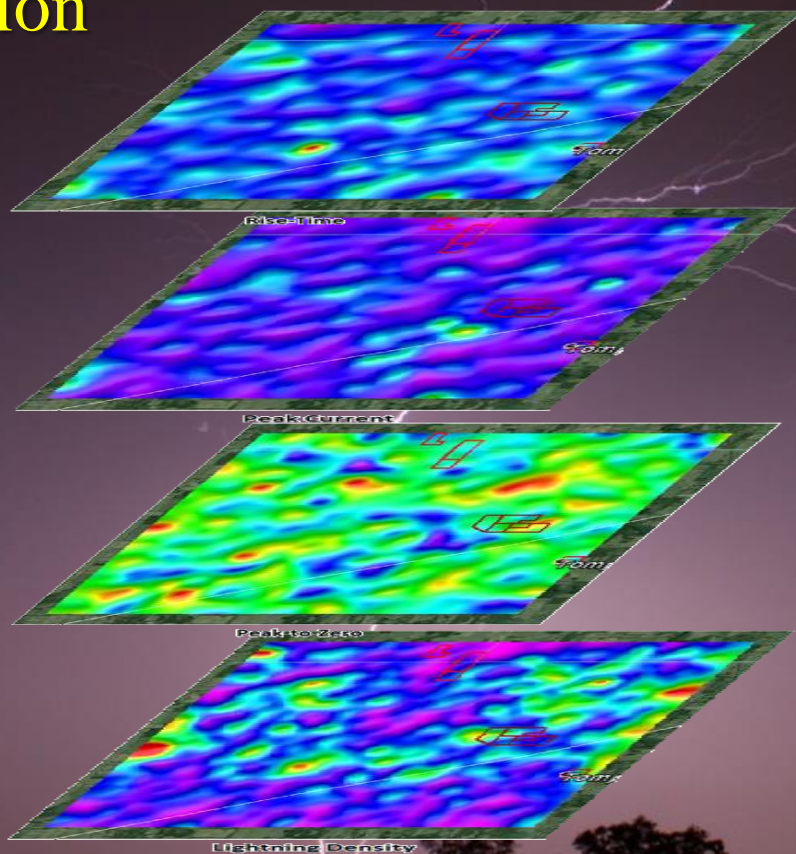
330 Sensors Record U.S. Lightning Strike Locations



Horizontal
Resolution
650' - 980'
(200-300 meters)

Lightning Strike Measurements

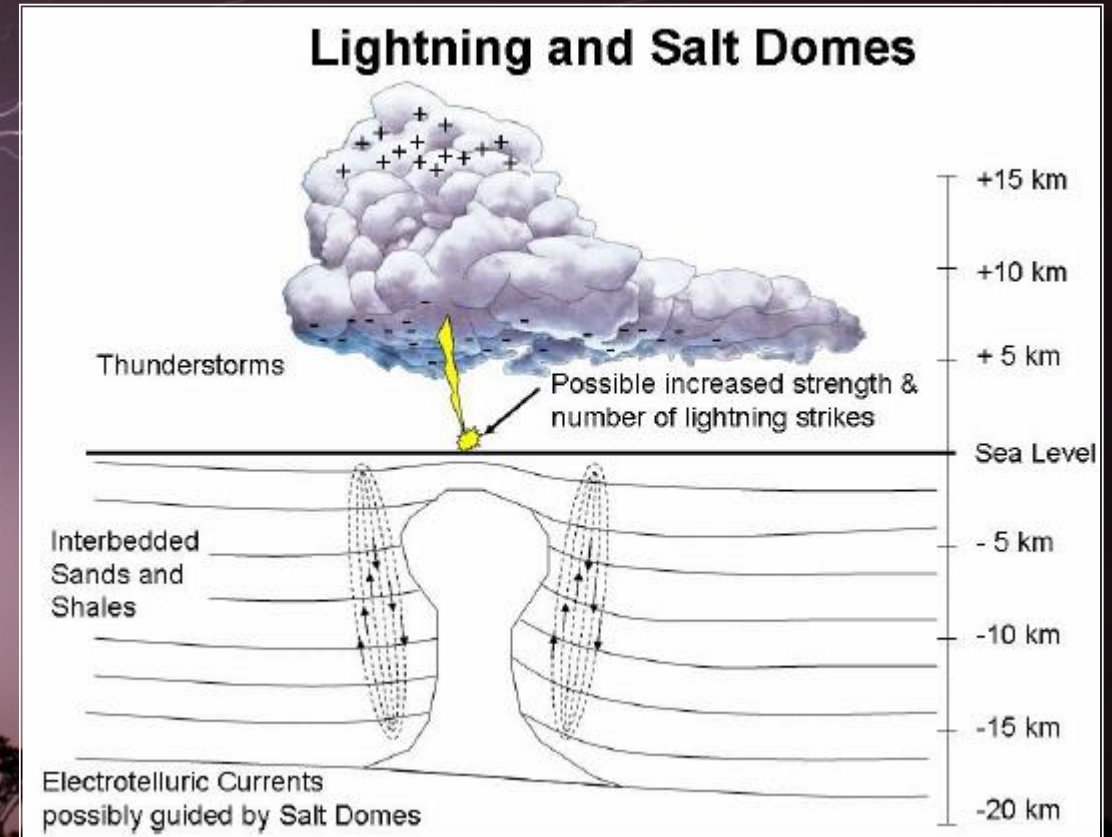
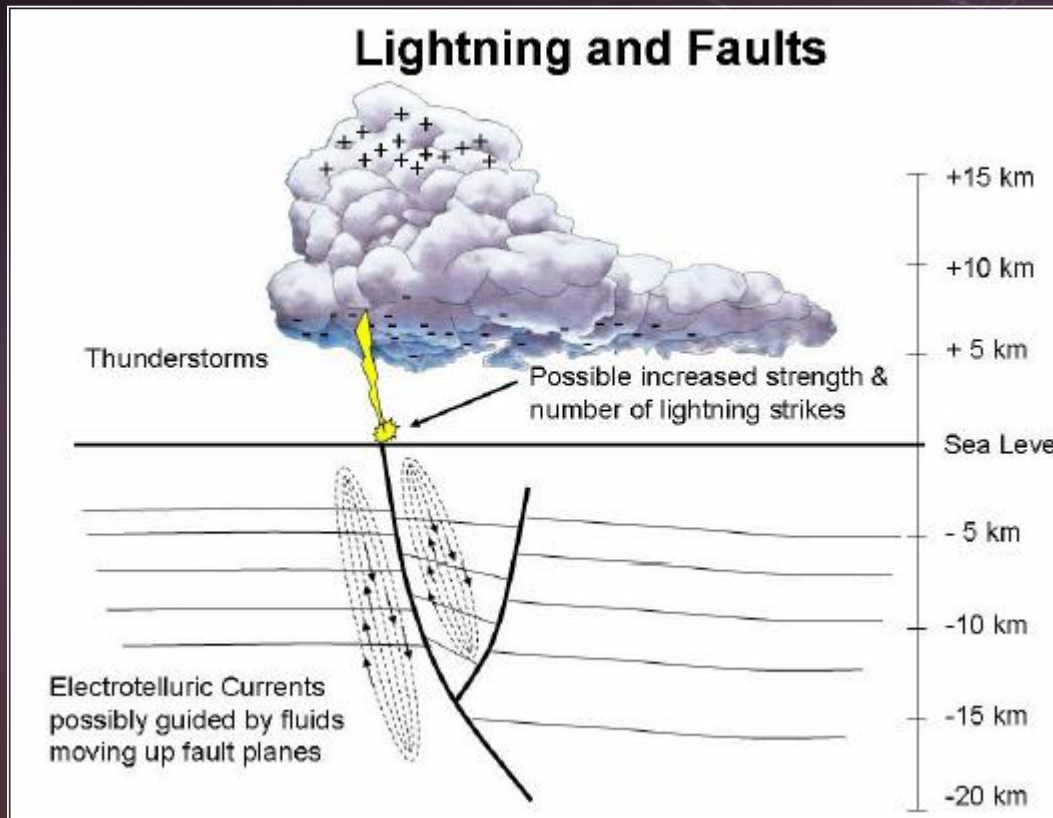
- Location
- Time and Duration
- Rise Time
- Peak Current
- Polarity
- Peak-to-Zero
- Density



Telluric Currents, Lightning & Geology



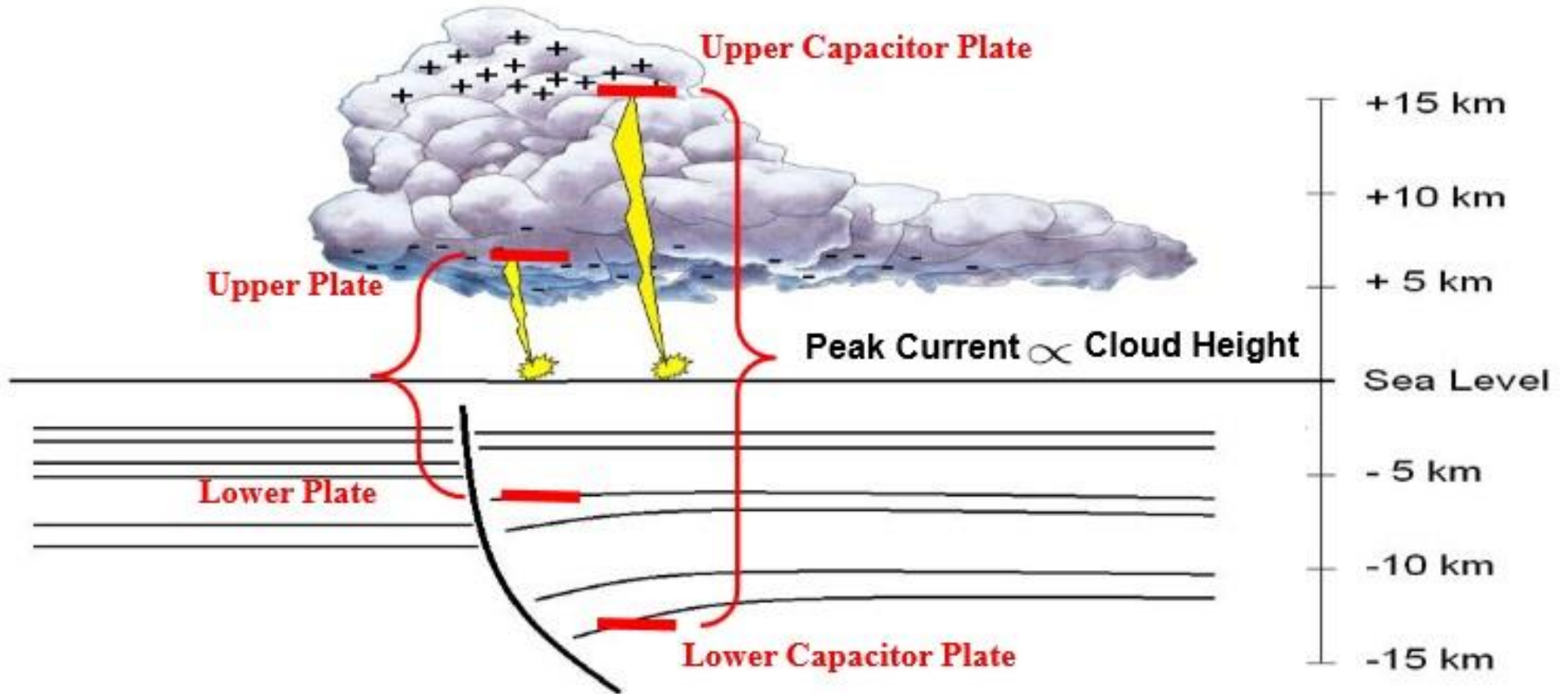
Earth Currents Modified by Geology → Prone to Lightning



Lightning Occurs when there is Sufficient Charge to Bridge Atmospheric Capacitor

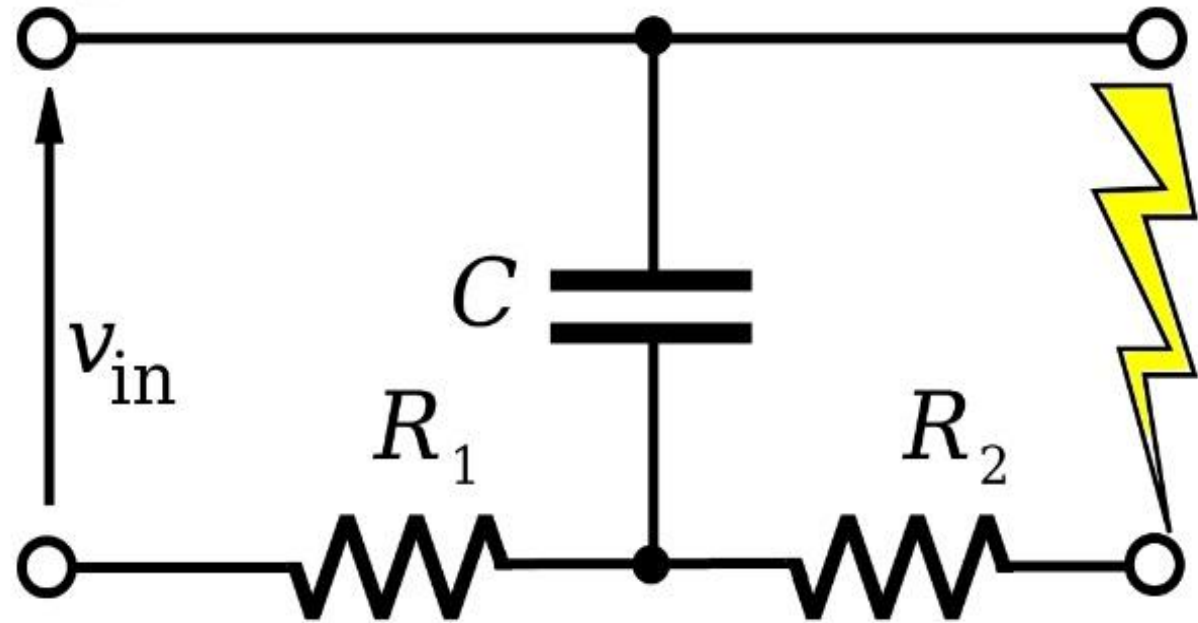


Millions of Lightning Strikes Millions of Measurements



Lightning

- The atmospheric capacitor is nearly the same
- 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



Lightning bypasses tall objects and...



...Infrastructure expected to attract lightning.



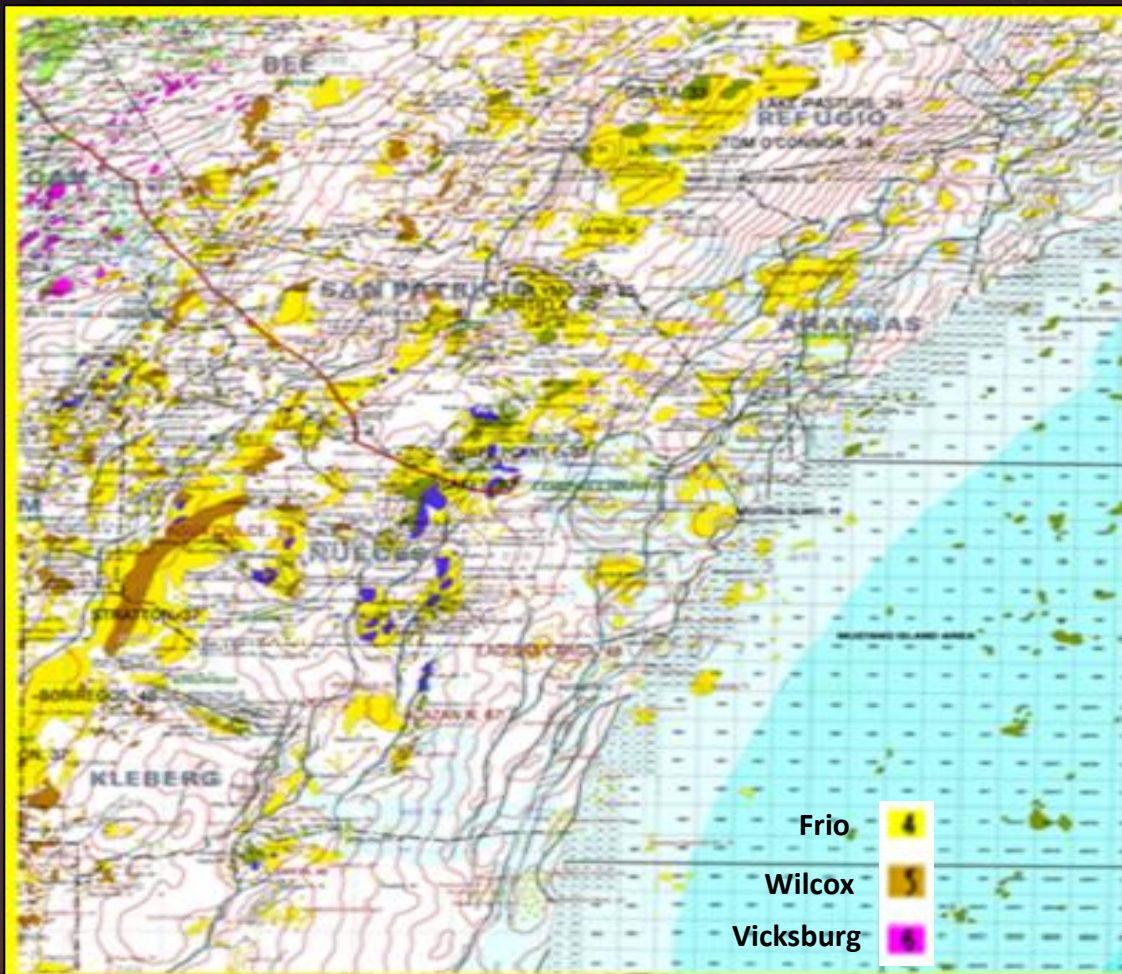
Upside Down Lightning
Enough Static Charge
to Produce Strike Originating
From the Ground



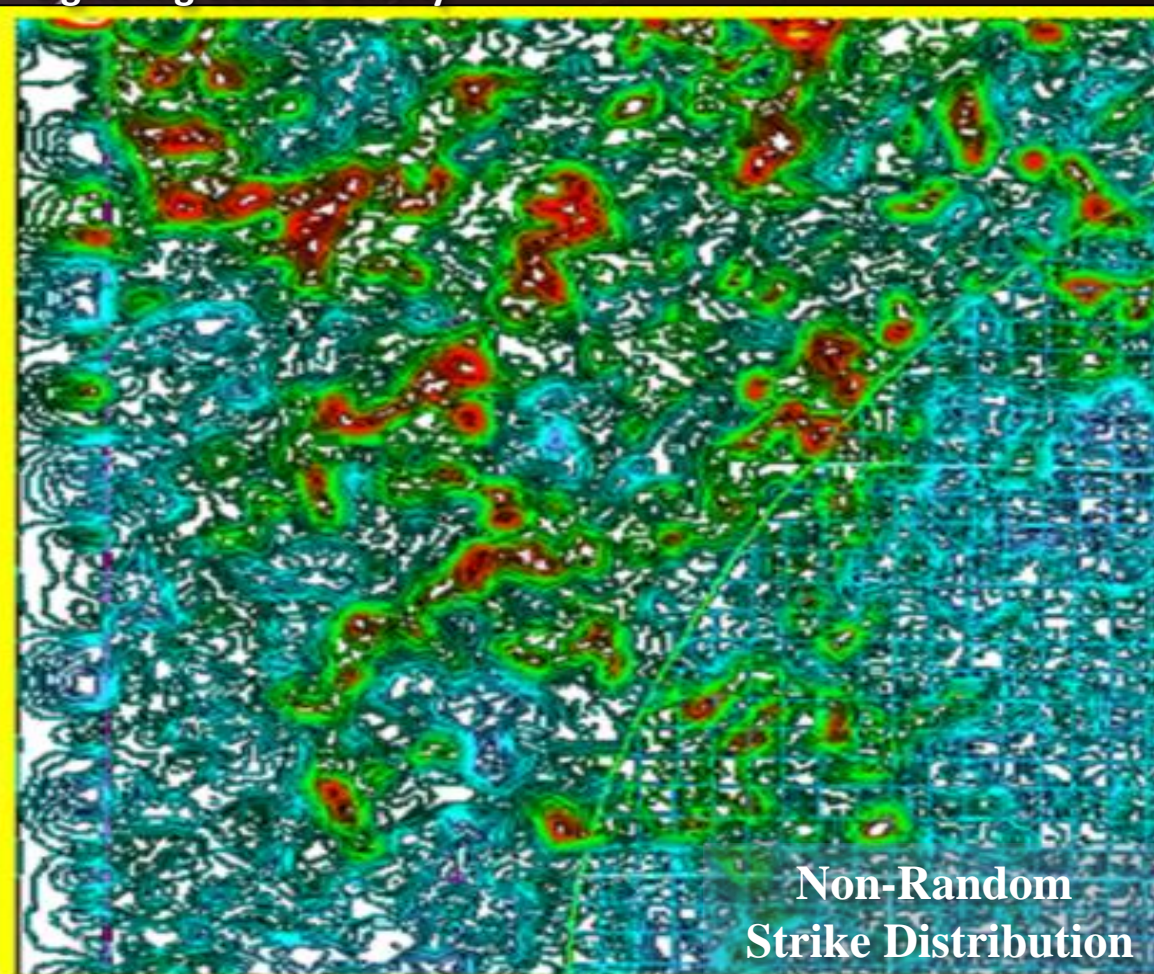
NSEM Correlates To Geology: Texas Gulf Coast Regional Correlation



Structure & Field Outlines



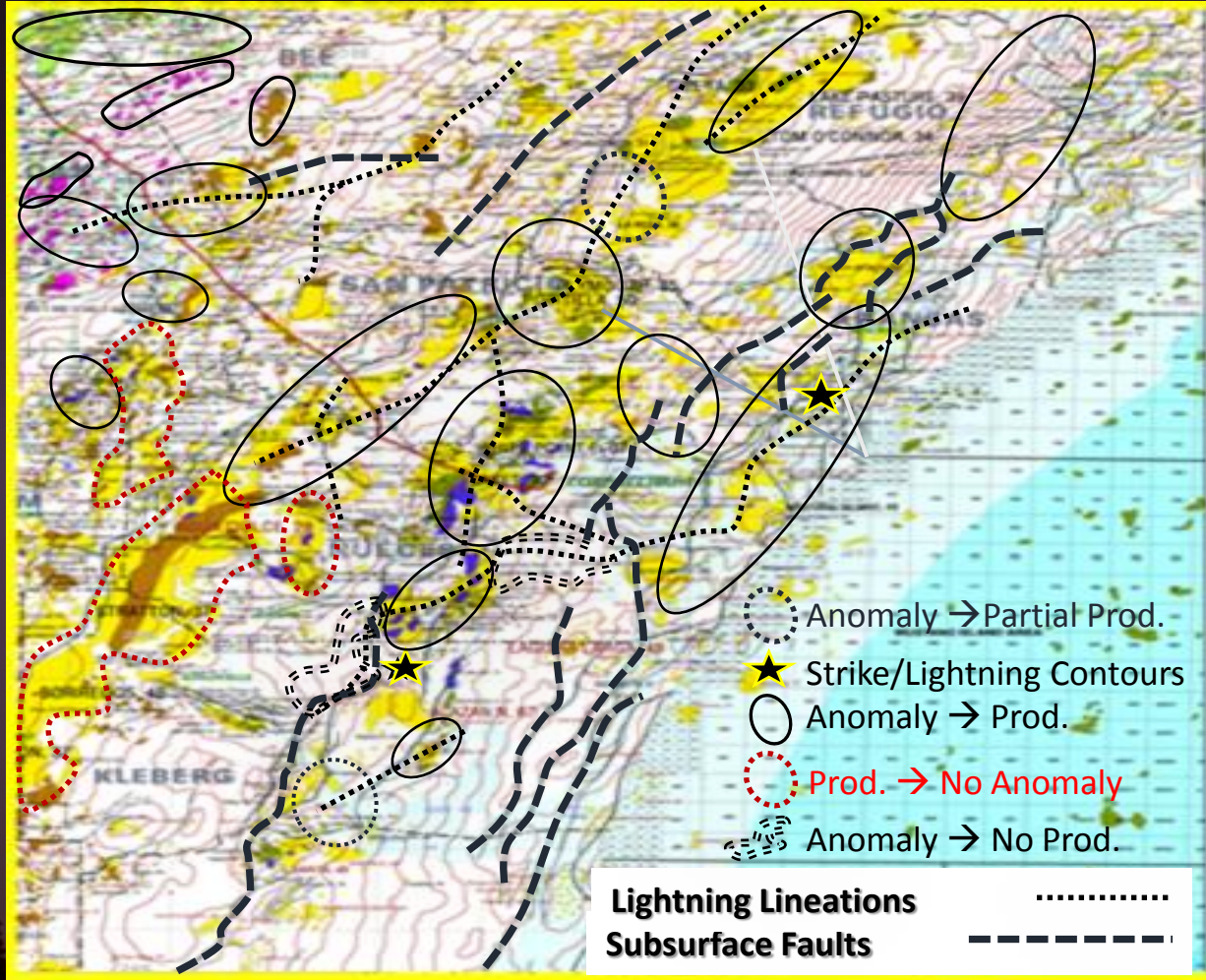
Lightning Strike Density



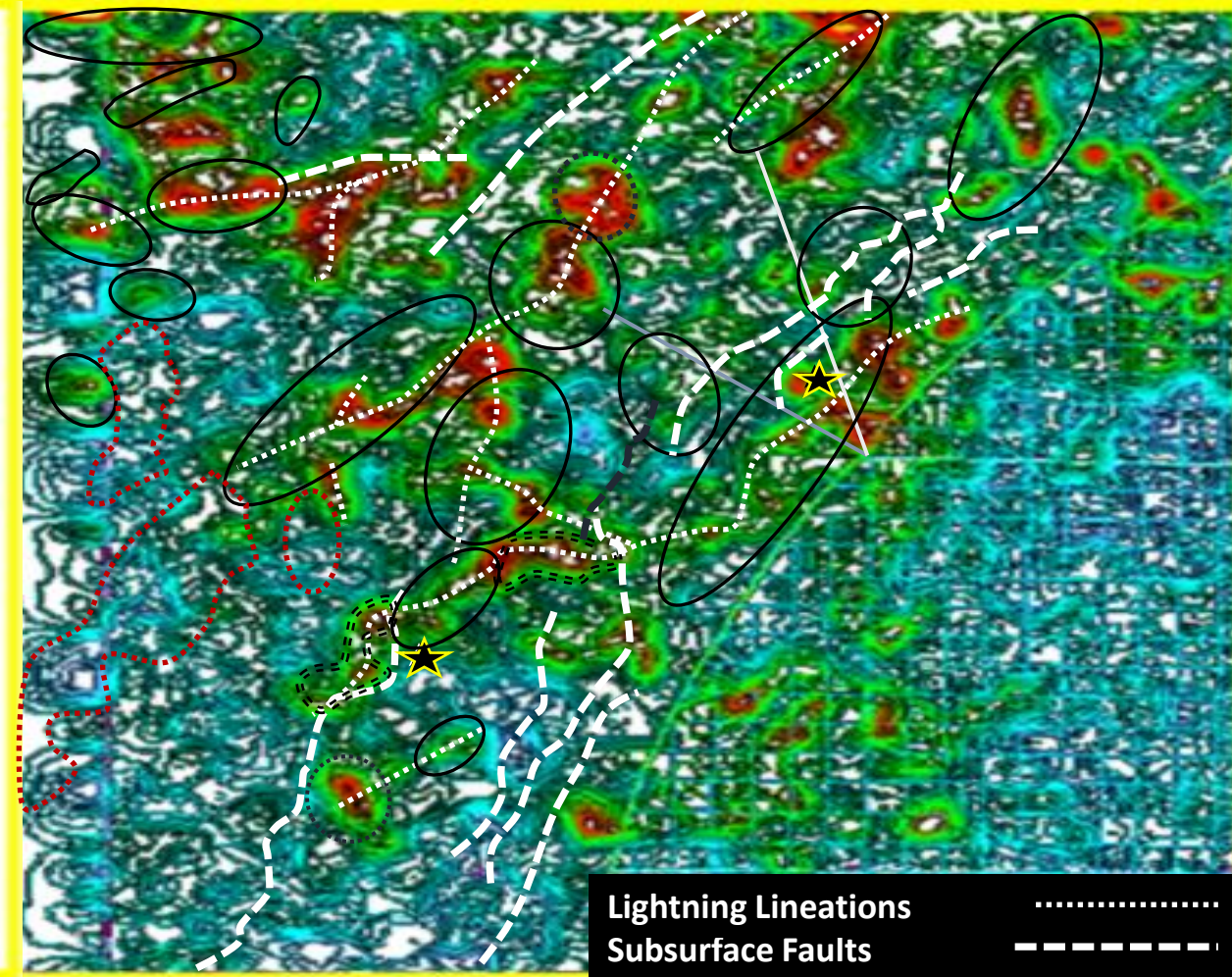
NSEM Correlates To Geology: Fault Patterns and Hydrocarbon Accumulations



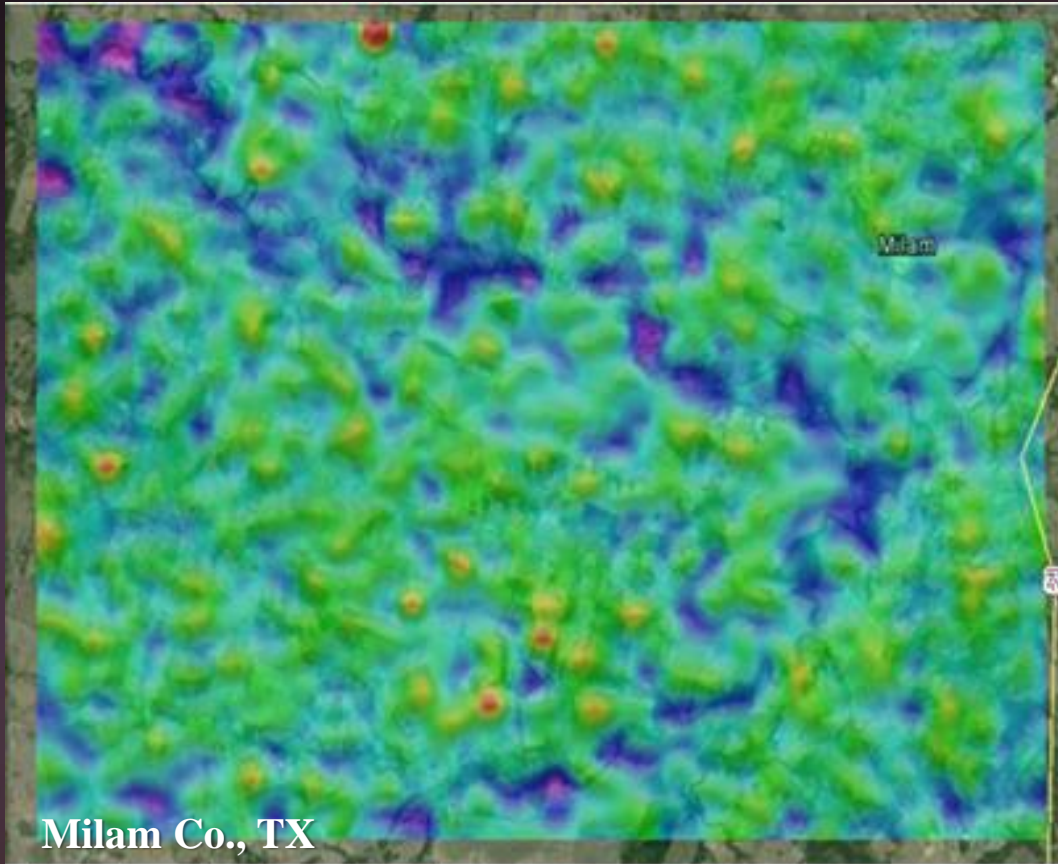
Structure & Field Outlines



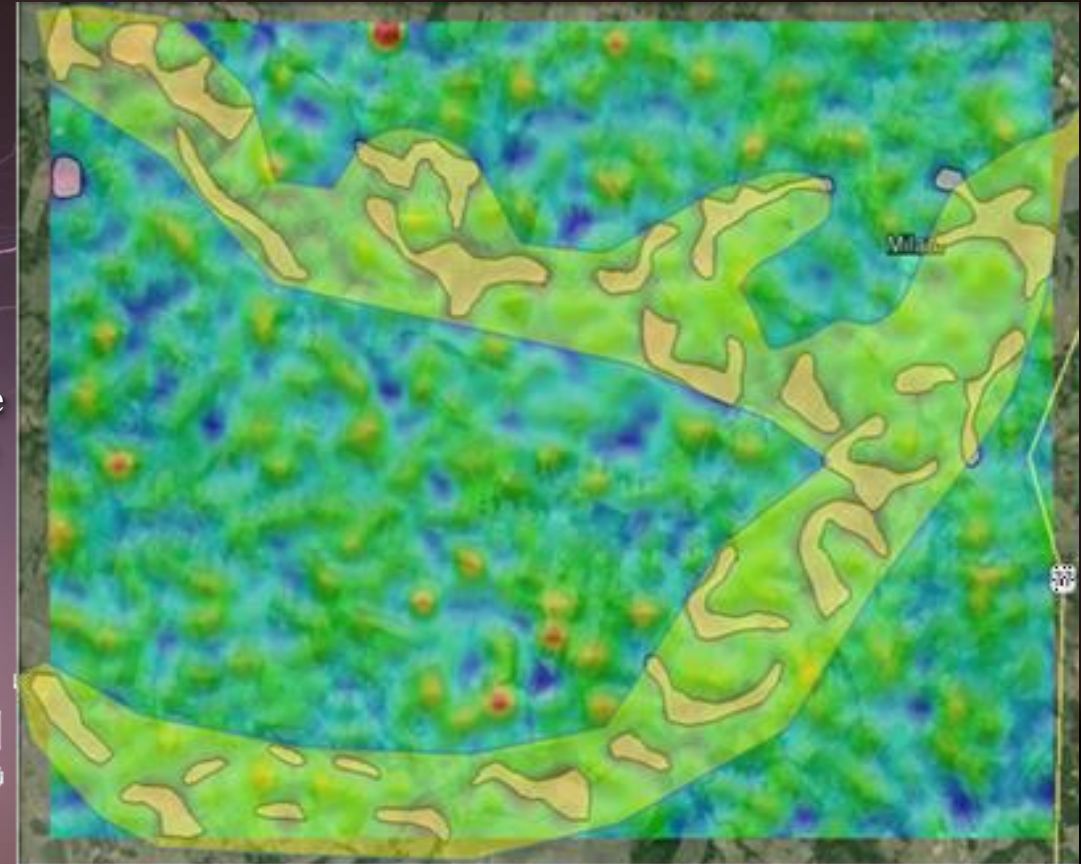
Lightning Strike Density



NSEM Correlates To Geology: Milam Co., TX Fluvial Depositional Patterns



Lightning Attribute
Rate of Rise-Time



Lightning is tied to all aspects
of the Earth's Electrical System

Geomagnetic Hot Zones

Top Plate

Powerline

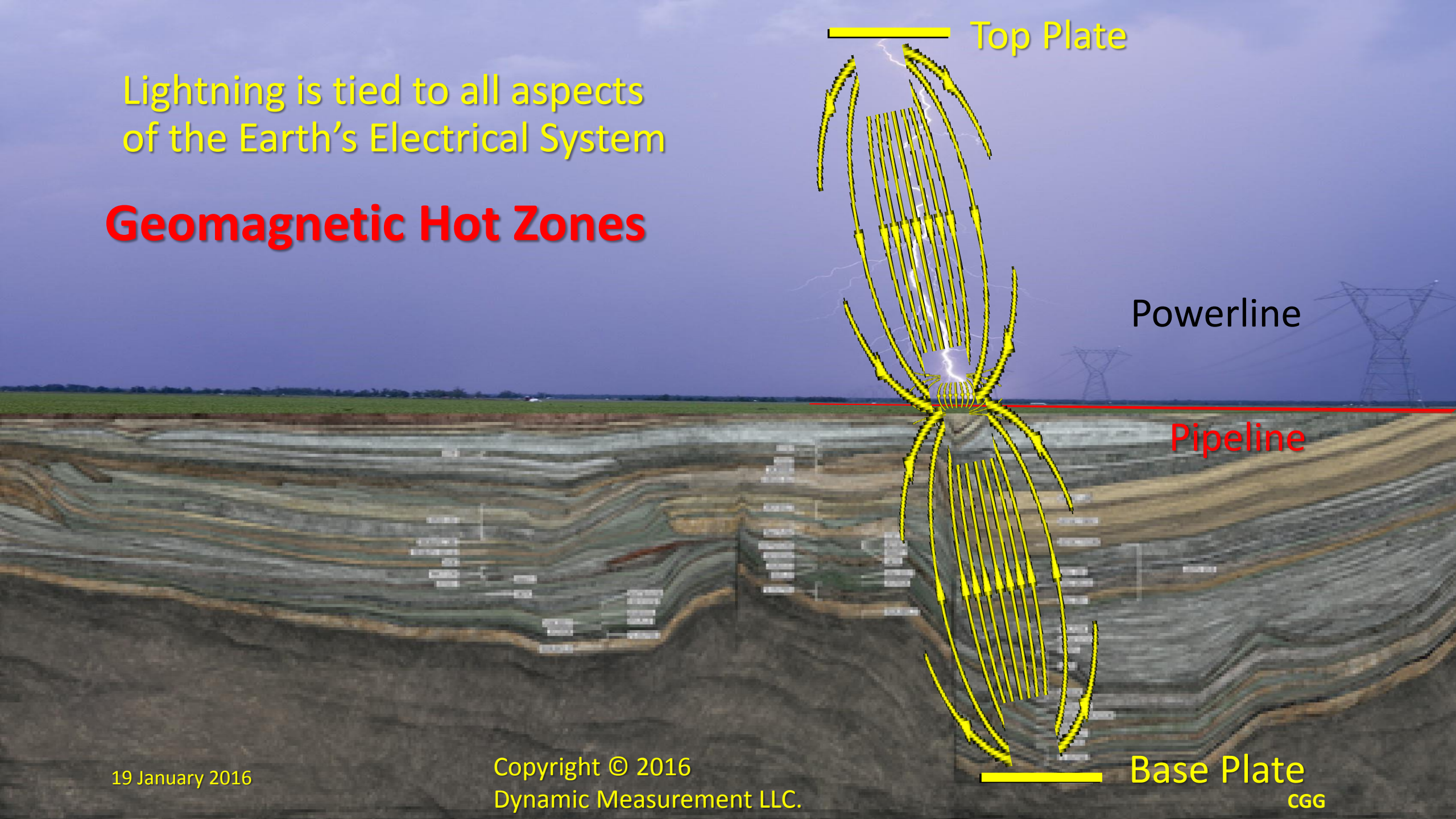
Pipeline

Base Plate

CGG

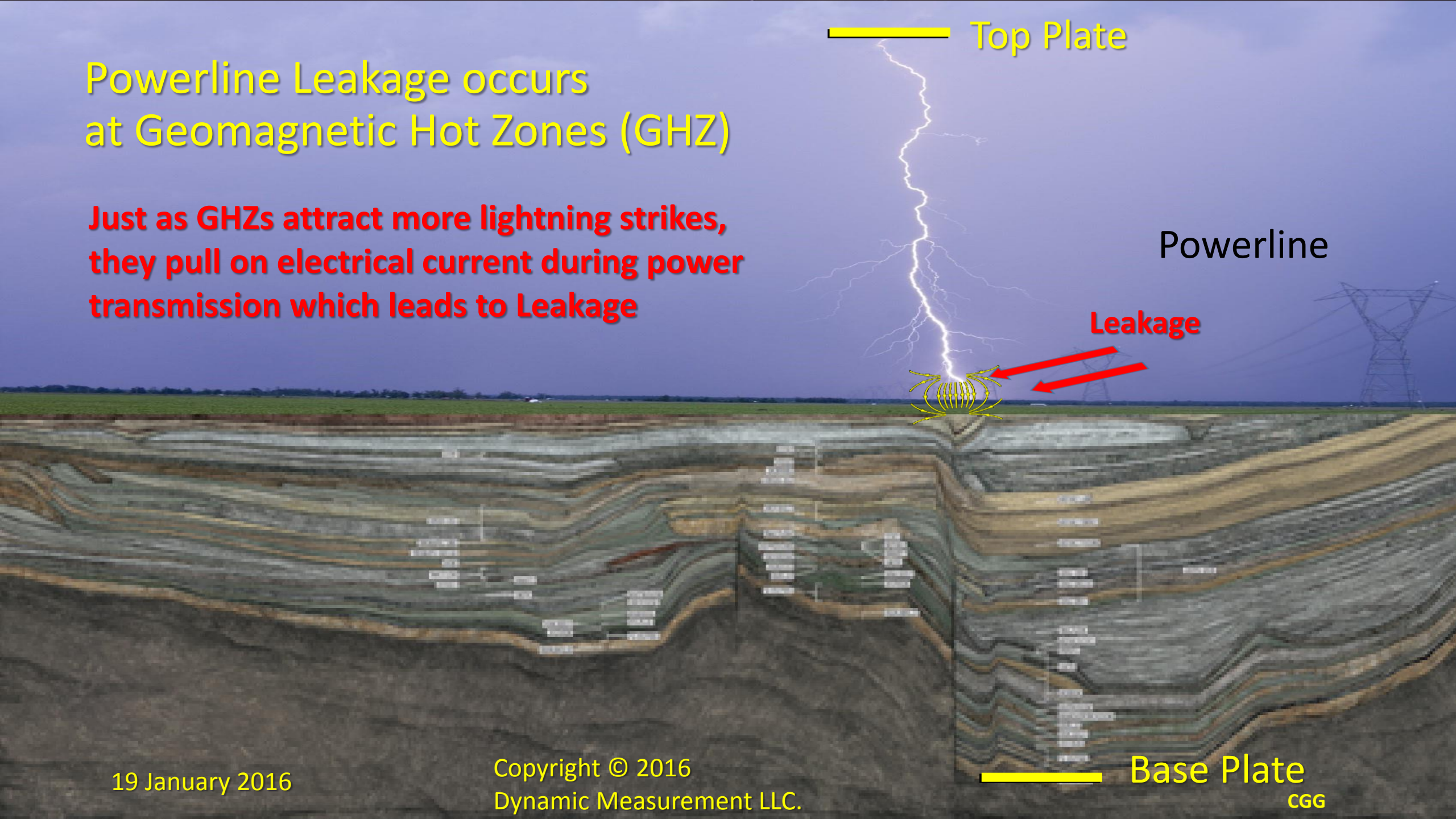
19 January 2016

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Powerline Leakage occurs at Geomagnetic Hot Zones (GHZ)

Just as GHZs attract more lightning strikes, they pull on electrical current during power transmission which leads to Leakage



Top Plate

Powerline

Leakage

Base Plate

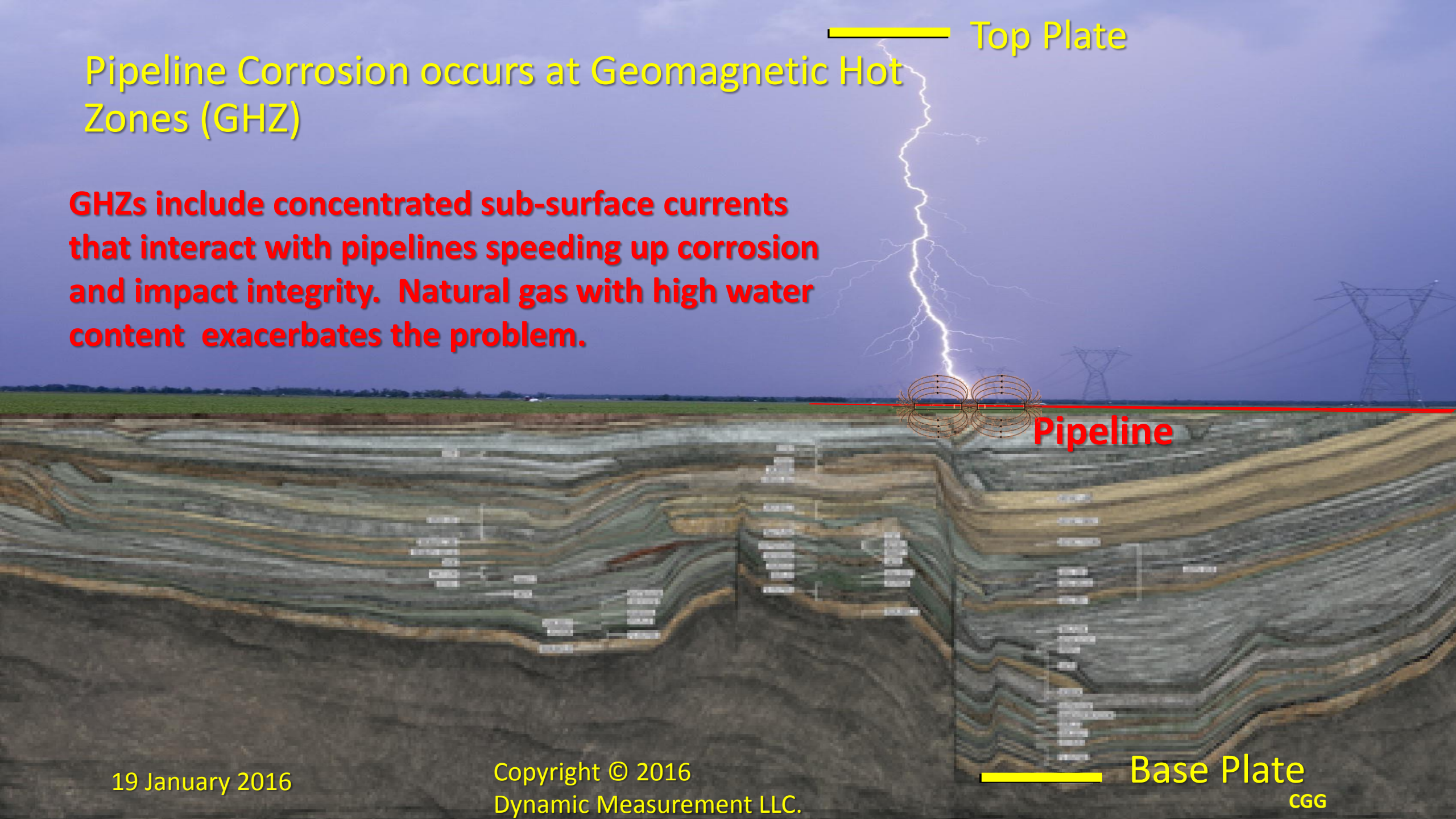
CGG

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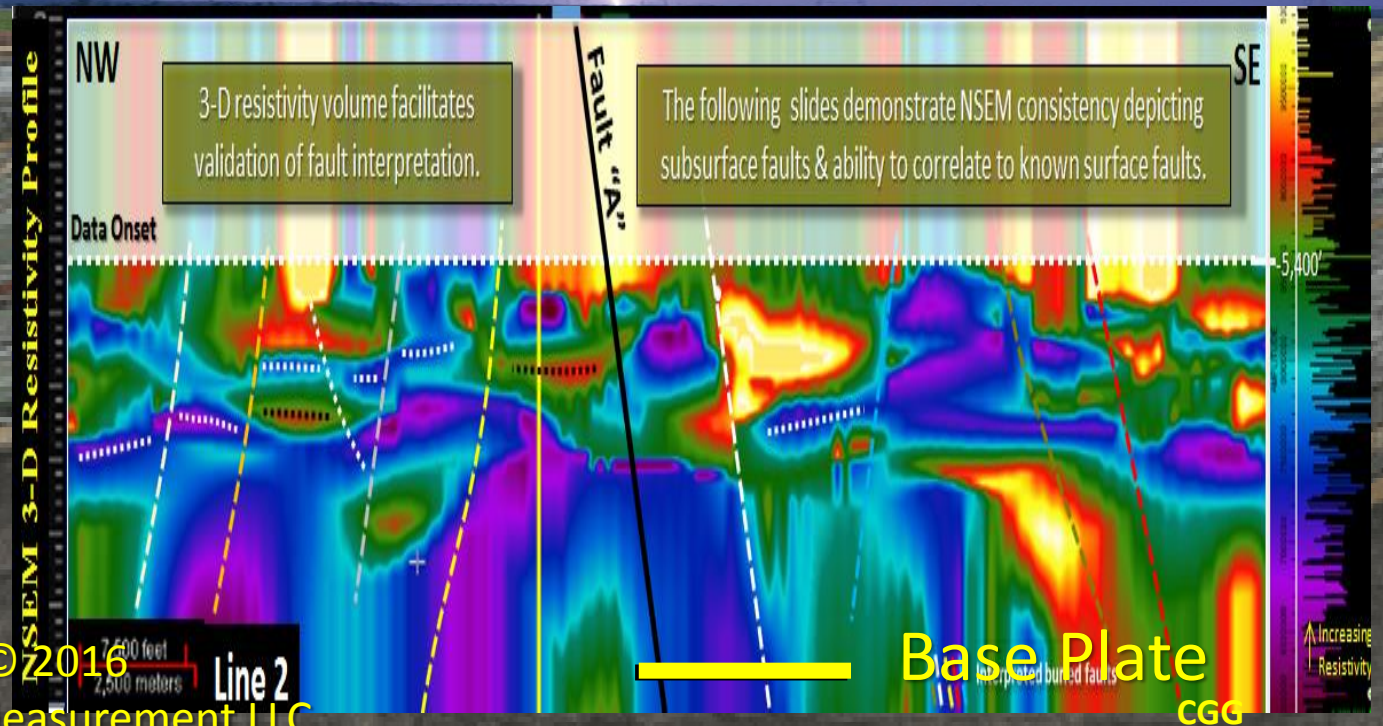
Pipeline Corrosion occurs at Geomagnetic Hot Zones (GHZ)

GHZs include concentrated sub-surface currents that interact with pipelines speeding up corrosion and impact integrity. Natural gas with high water content exacerbates the problem.



Lightning Resistivity Volumes define the Geologic Framework and Extent of Geomagnetic Hot Zones

Top Plate



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Proven & Patented Technology



Fig. 1



US008344721B2

(12) **United States Patent**
Nelson, Jr. et al.

(10) **Patent No.:** US 8,344,721 B2
(45) **Date of Patent:** Jan. 1, 2013

(54) **METHOD FOR LOCATING SUB-SURFACE NATURAL RESOURCES**

(75) **Inventors:** H. Roice Nelson, Jr., Houston, TX (US); Joseph H. Roberts, Houston, TX (US); D. James Siebert, Katy, TX (US); Wulf F. Massell, Conroe, TX (US); Samuel D. LeRoy, Houston, TX (US); Leslie R. Denham, Houston, TX (US); Robert Ehrlich, Salt Lake City, UT (US); Richard L. Coons, Katy, TX (US)

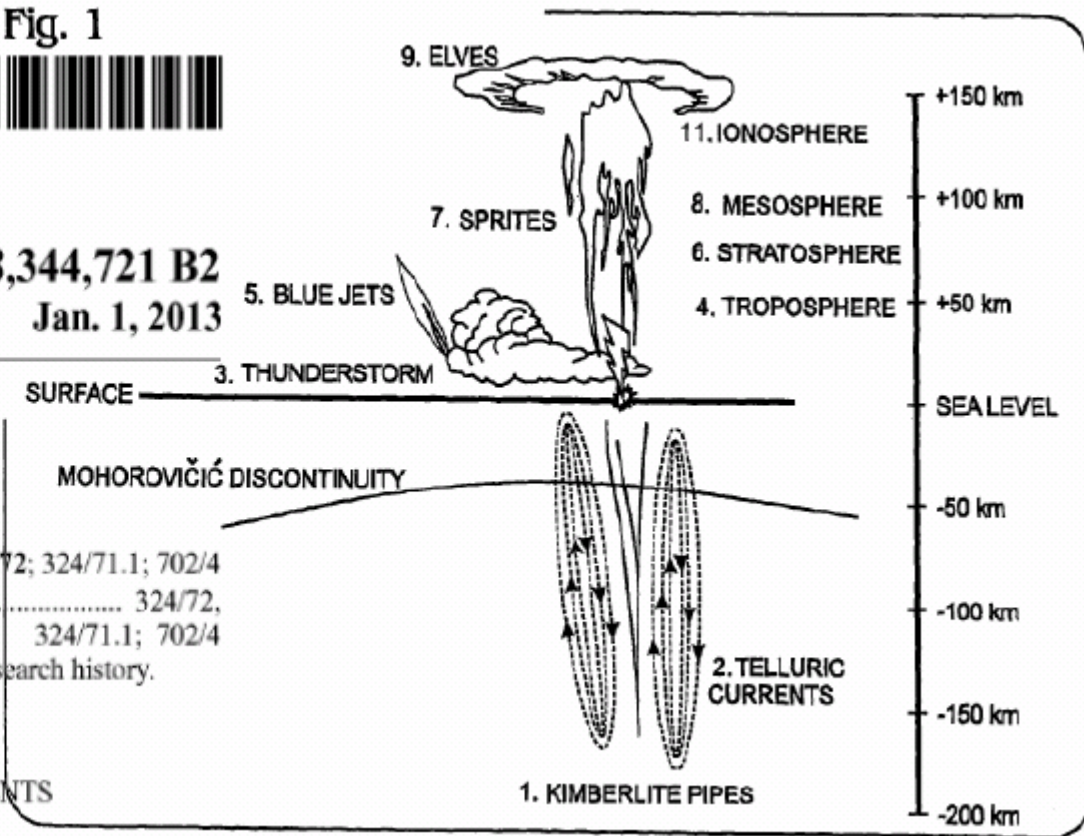
(51) **Int. Cl.**
G01R 31/02 (2006.01)
G01N 27/00 (2006.01)
G01W 1/00 (2006.01)

(52) **U.S. Cl.** 324/72; 324/71.1; 702/4

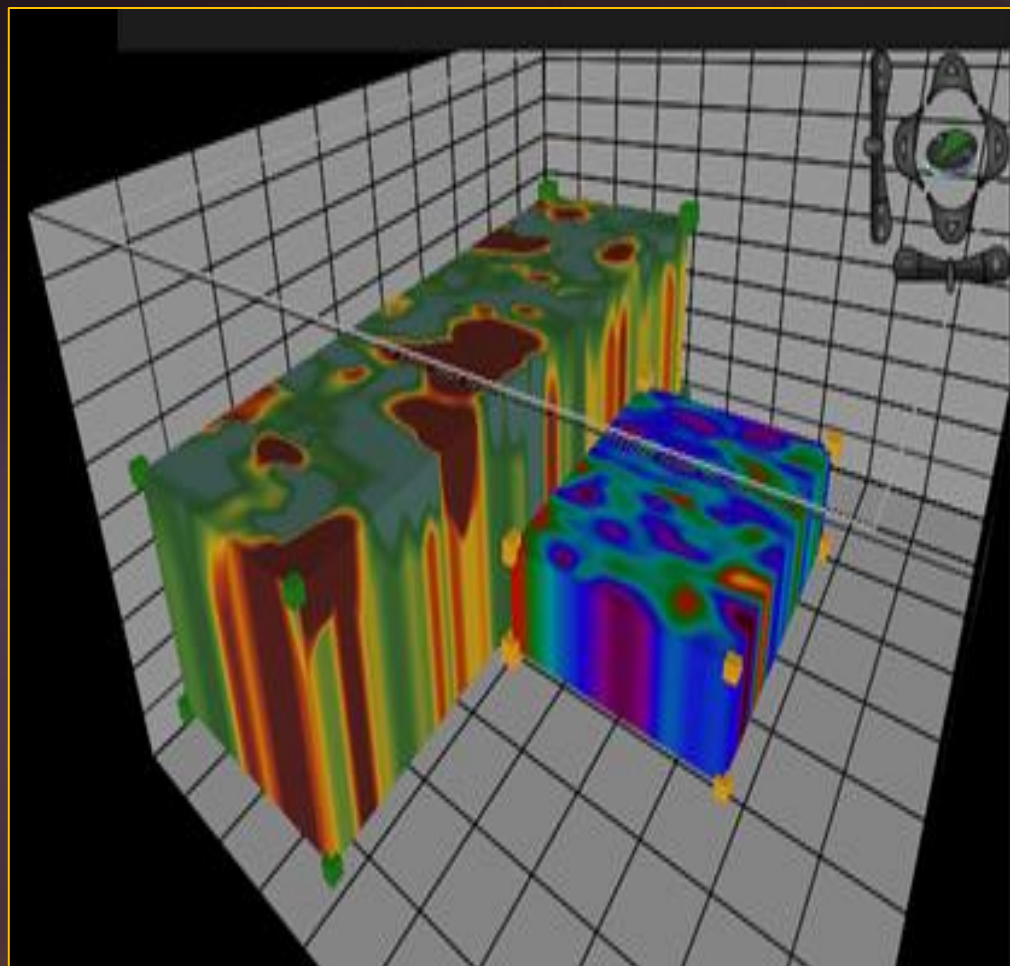
(58) **Field of Classification Search** 324/72, 324/71.1; 702/4

See application file for complete search history.

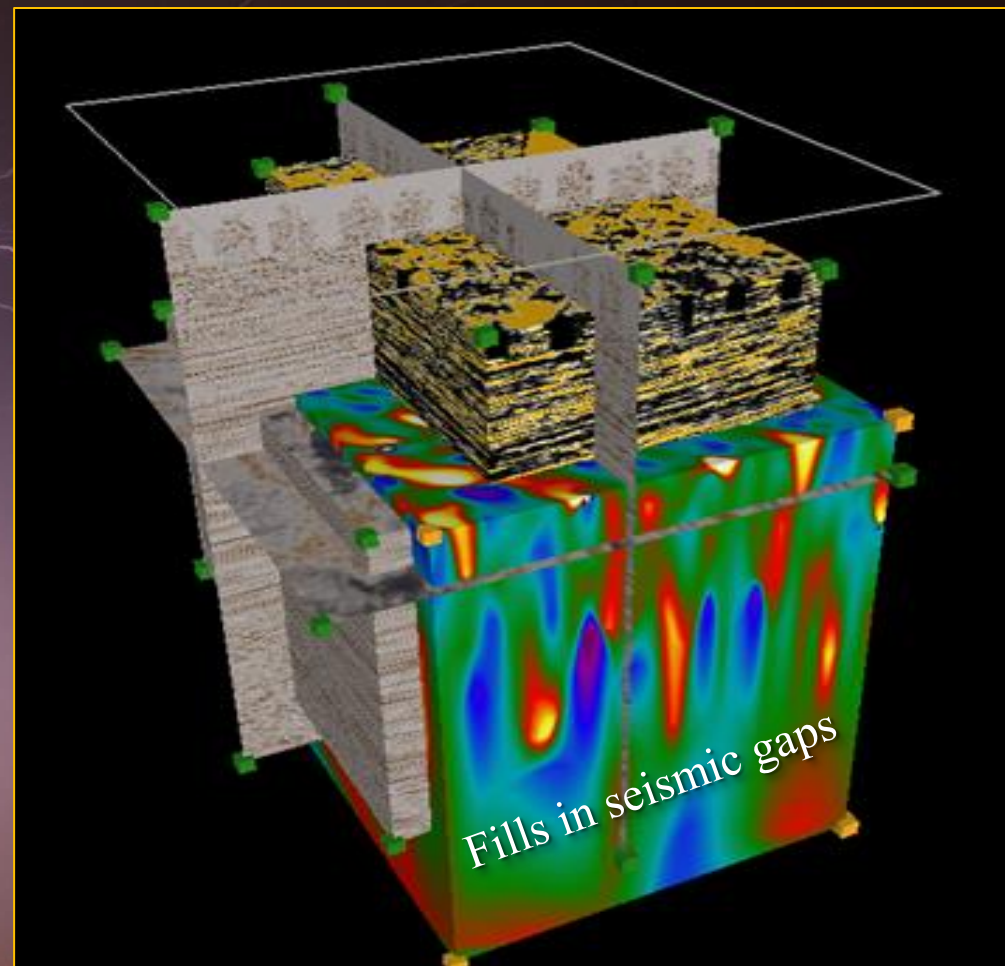
(56) **References Cited**
U.S. PATENT DOCUMENTS



Resistivity & Permittivity Volumes Easily Integrated with 3-D Seismic & Well Data



Inlines
Crosslines
Arb Lines
Slices

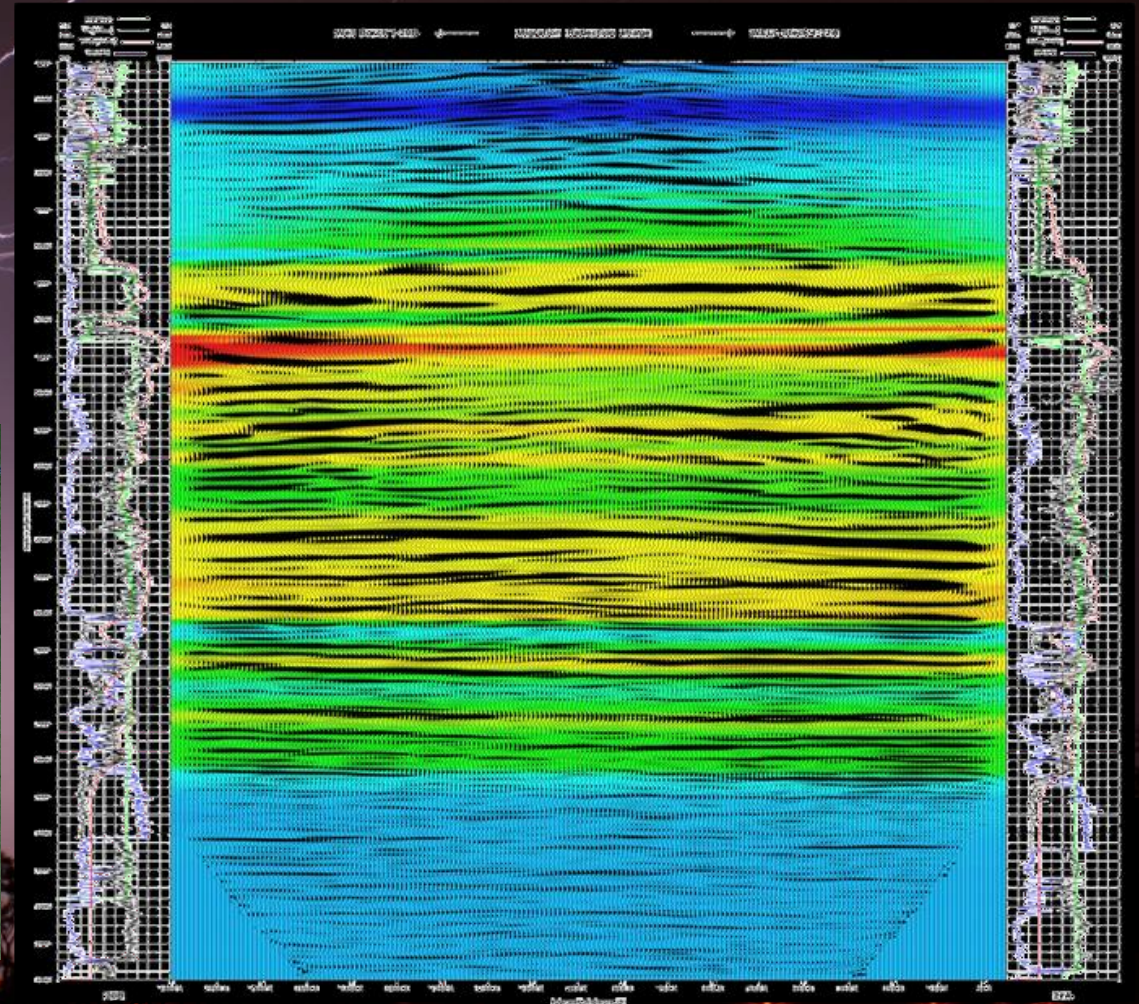
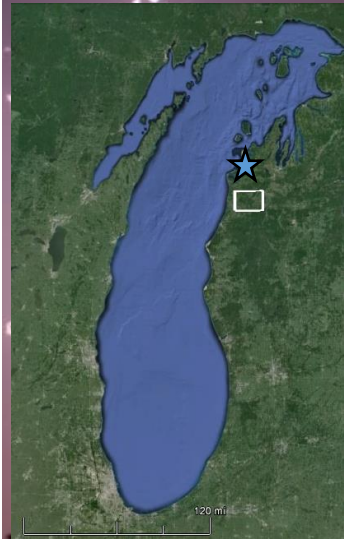
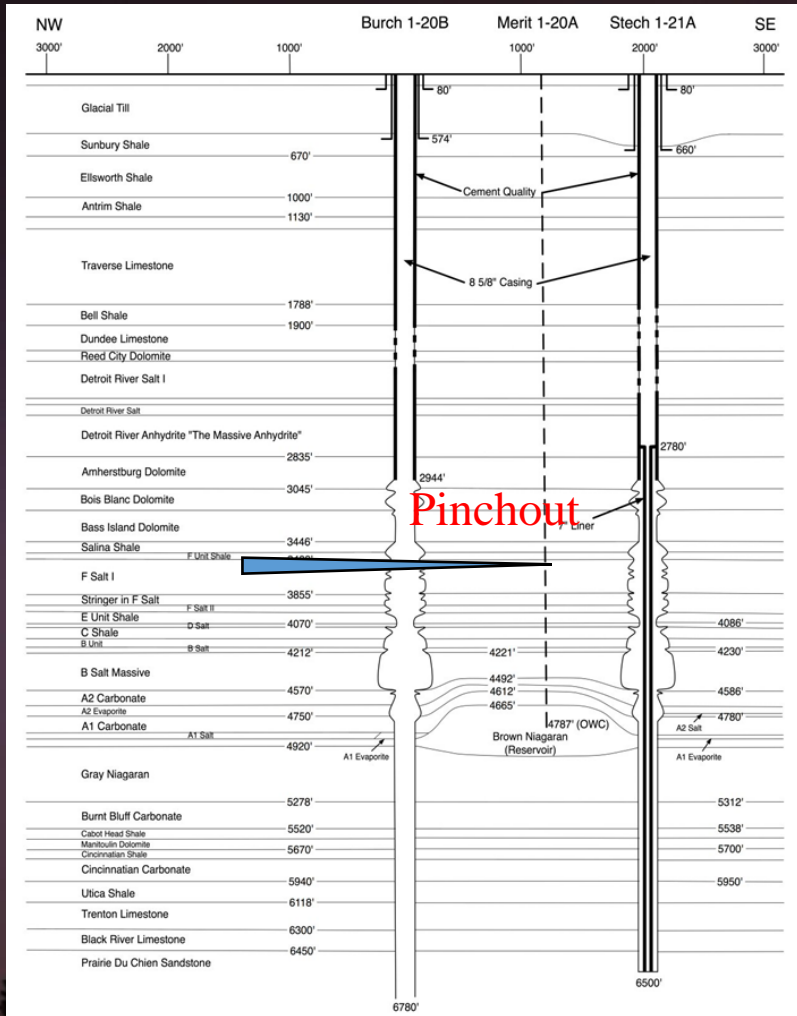


Michigan Technology University Cross Well Tomography

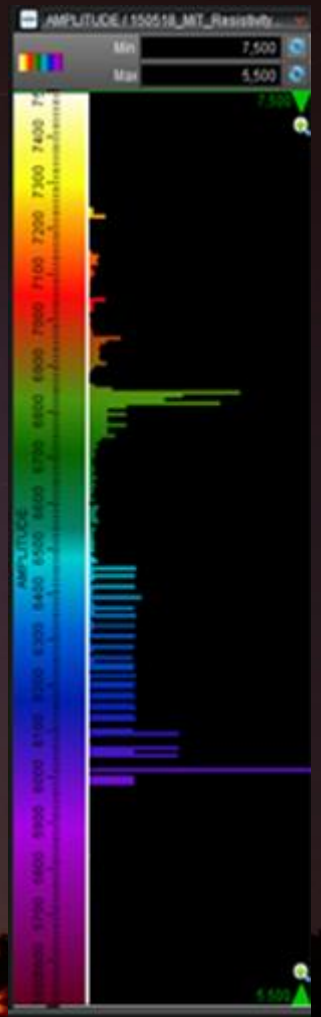
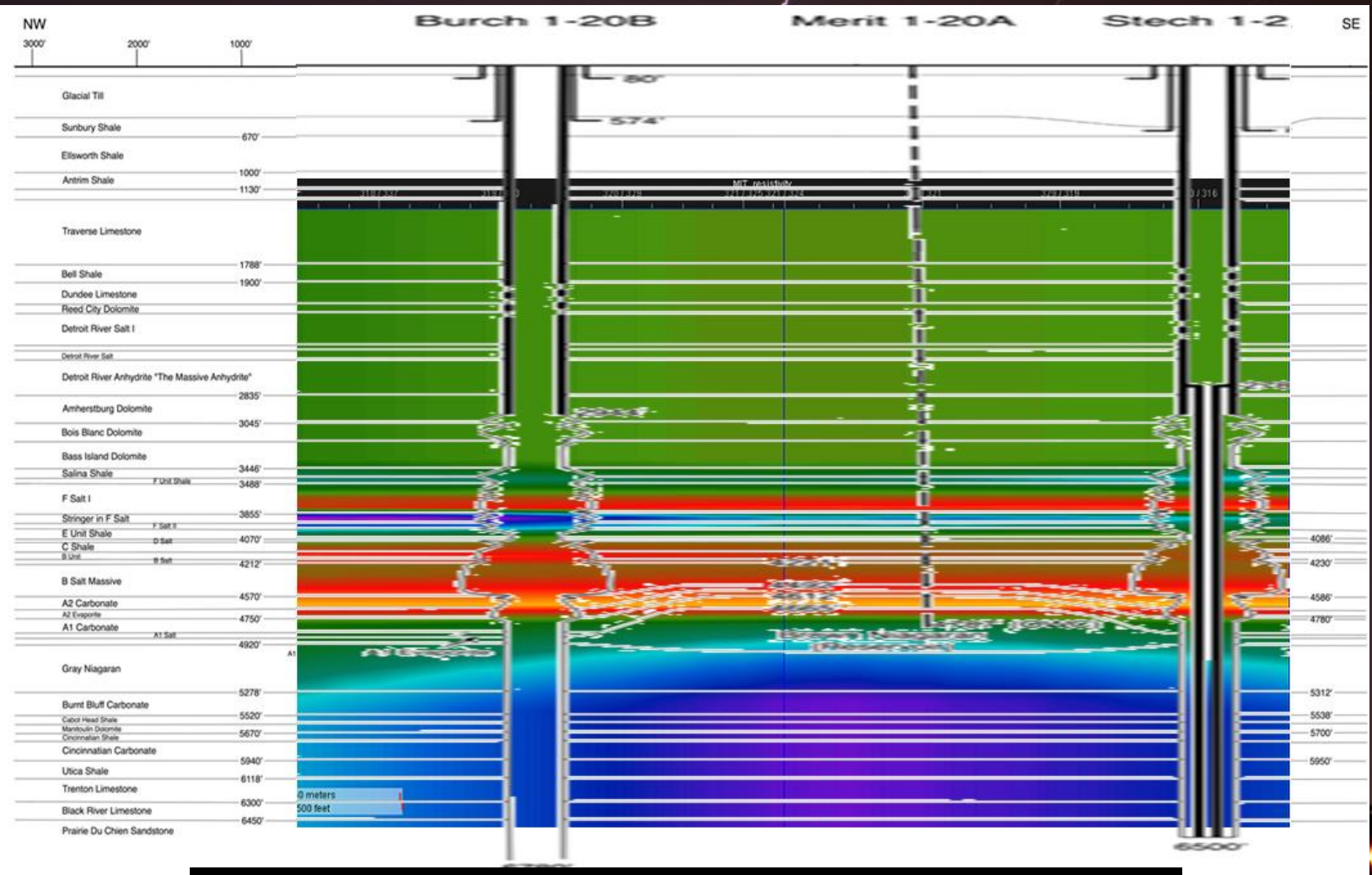
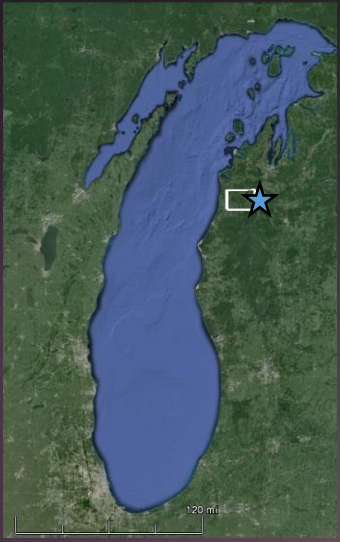


Depth and Amplitude Calibration

MTU Test Site with Cross-Well Tomography

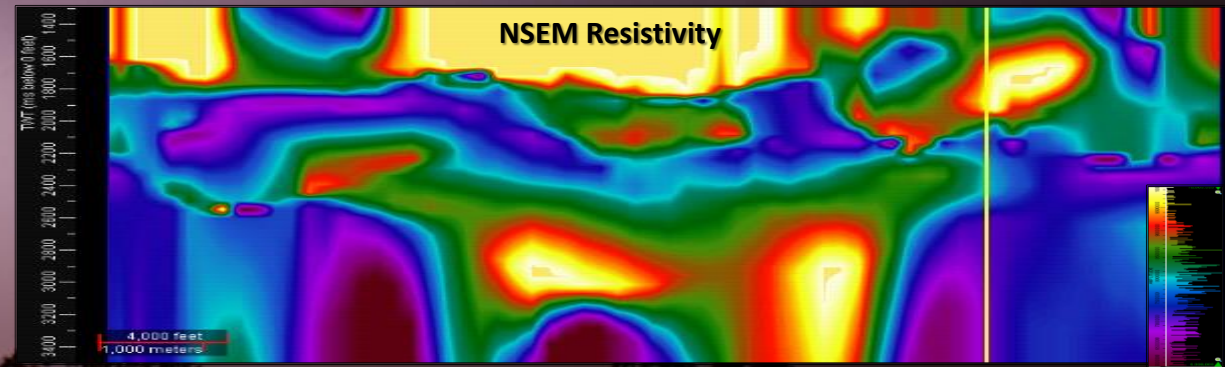
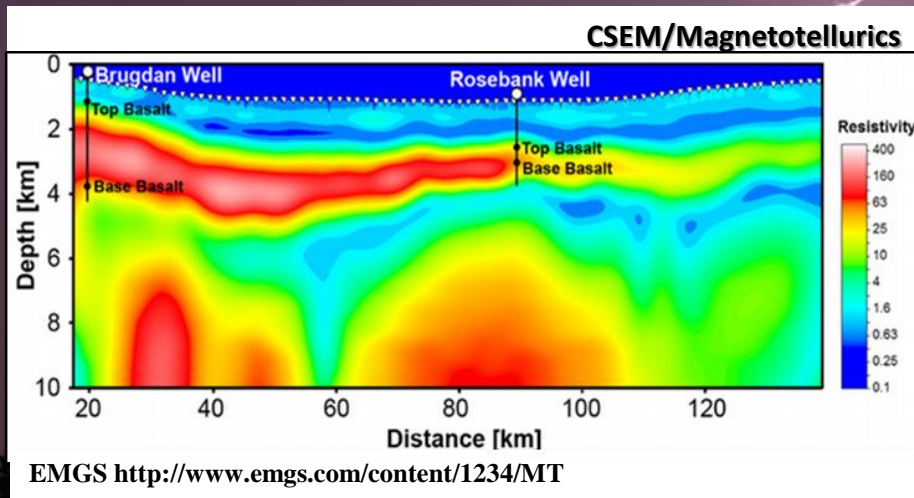
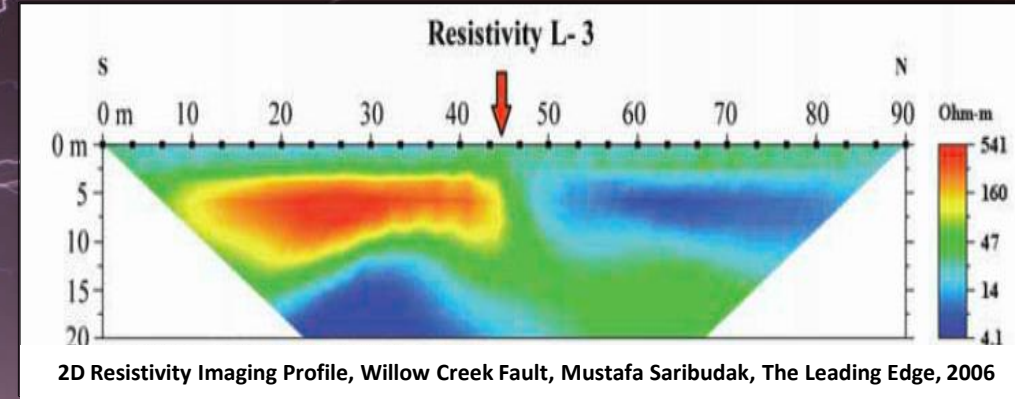
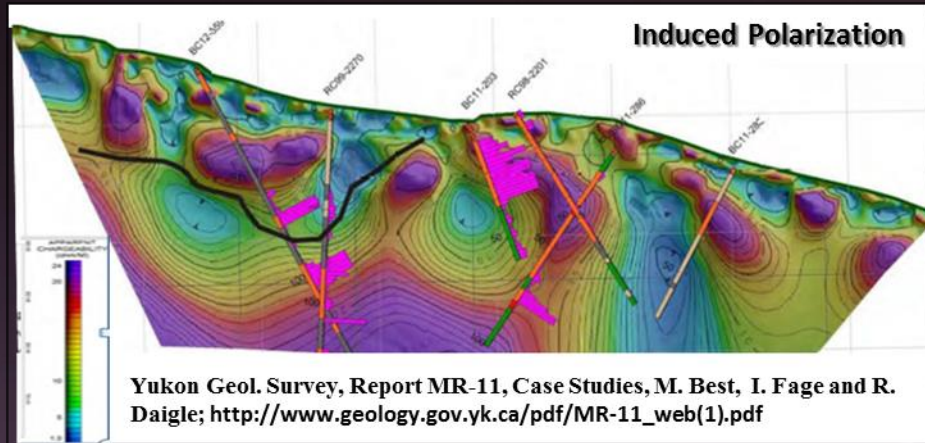


MTU Test Site Wells Overlaid on Resistivity Section

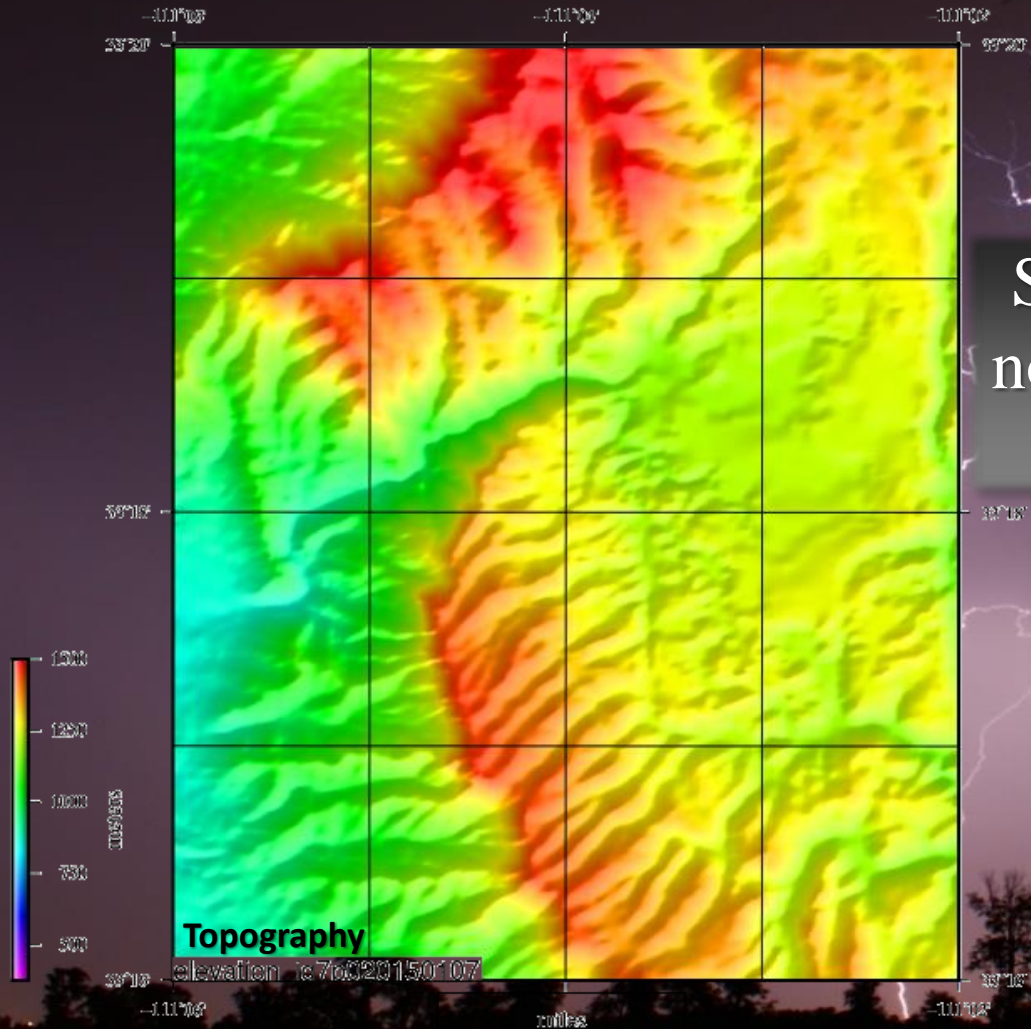


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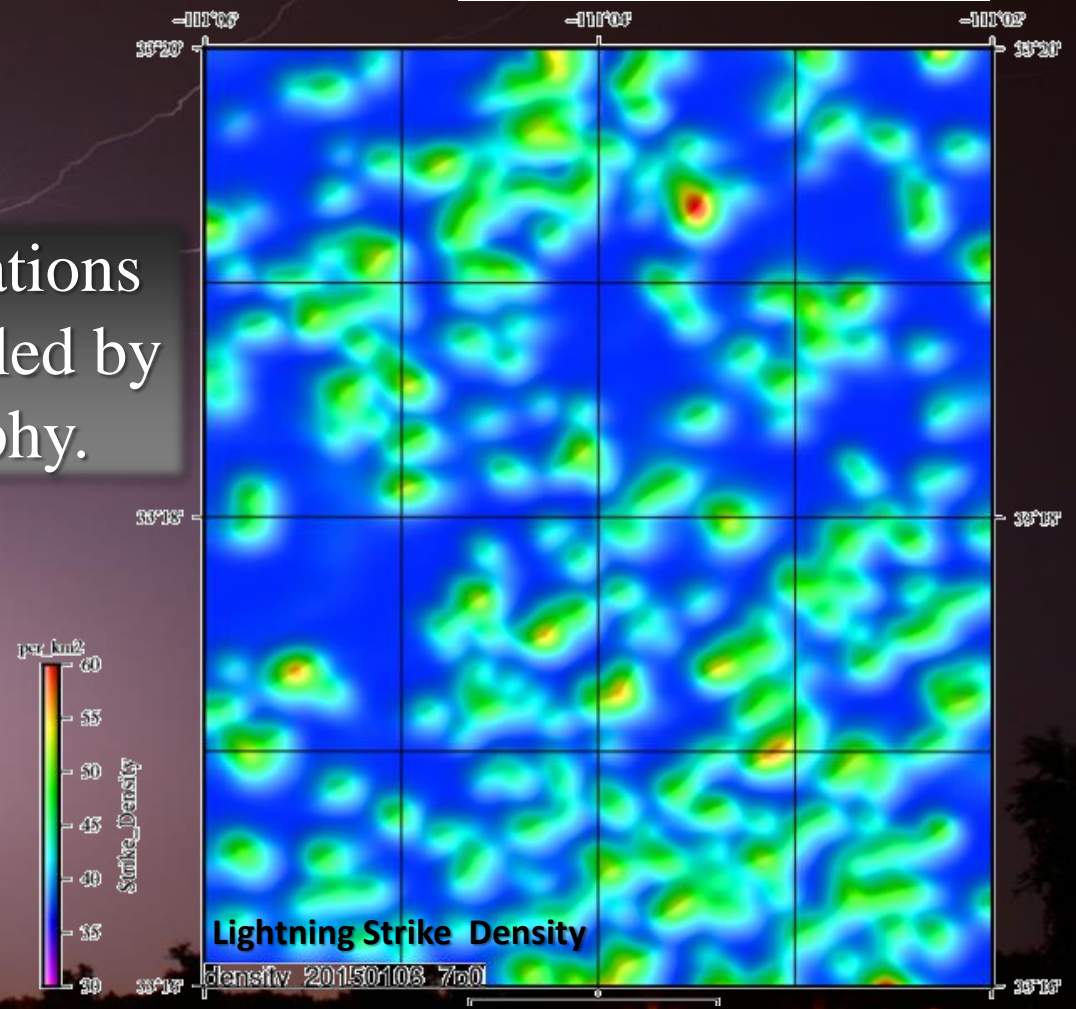
Resistivity & Permittivity Volumes Easily Integrated with Near-Surface Geophysical Data

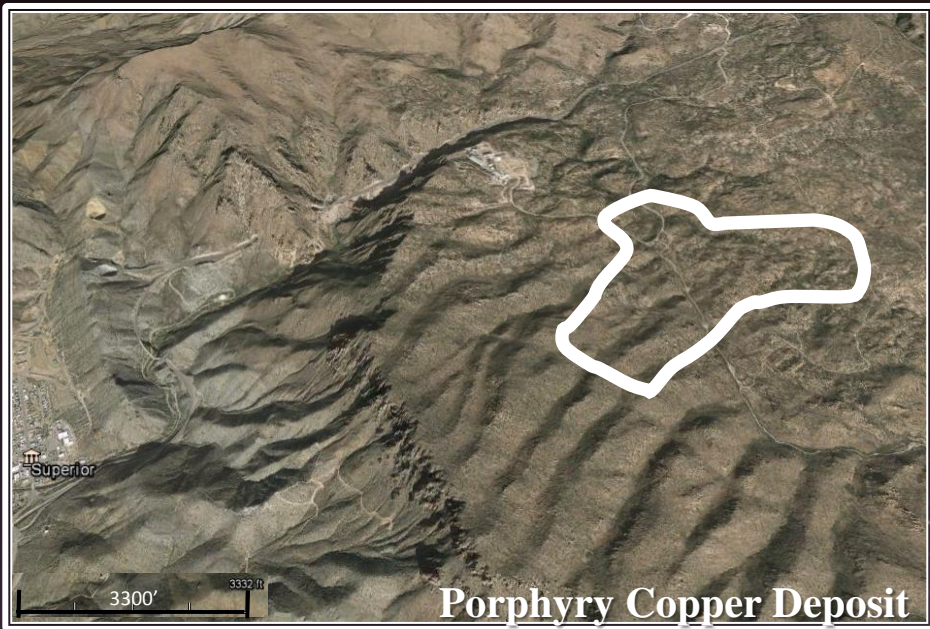


Topography and Lightning Density Pinal Co., AZ

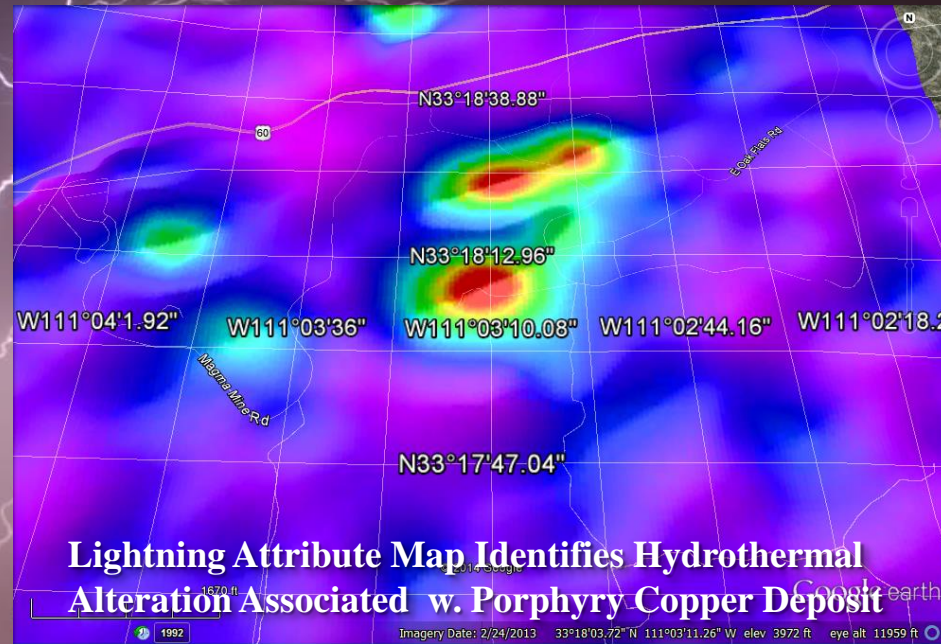
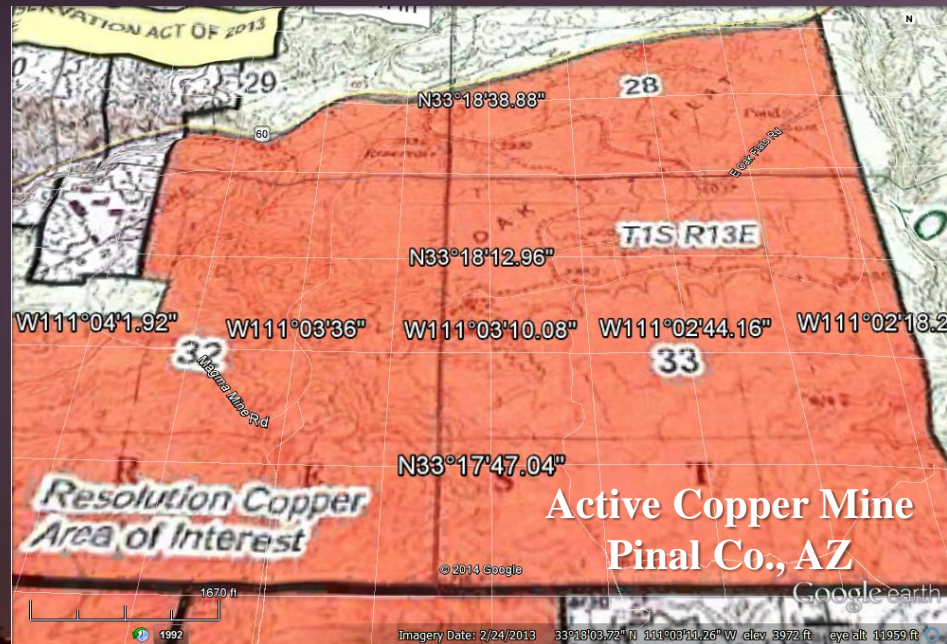


Strike locations
not controlled by
topography.





NSEM Correlates To Rock Properties: Mineral Exploration



DML's Technology is being Recognized



GULF COAST ASSOCIATION OF GEOLOGICAL SOCIETIES

www.gcags.org



Dear Kathleen,

Congratulations! You have been selected to receive the First Place Grover E. Murray Best Published Paper Award for your paper, "Aquifers, Faults, Subsidence, and Lightning Databases" published in the 2014 GCAGS *Transactions*.

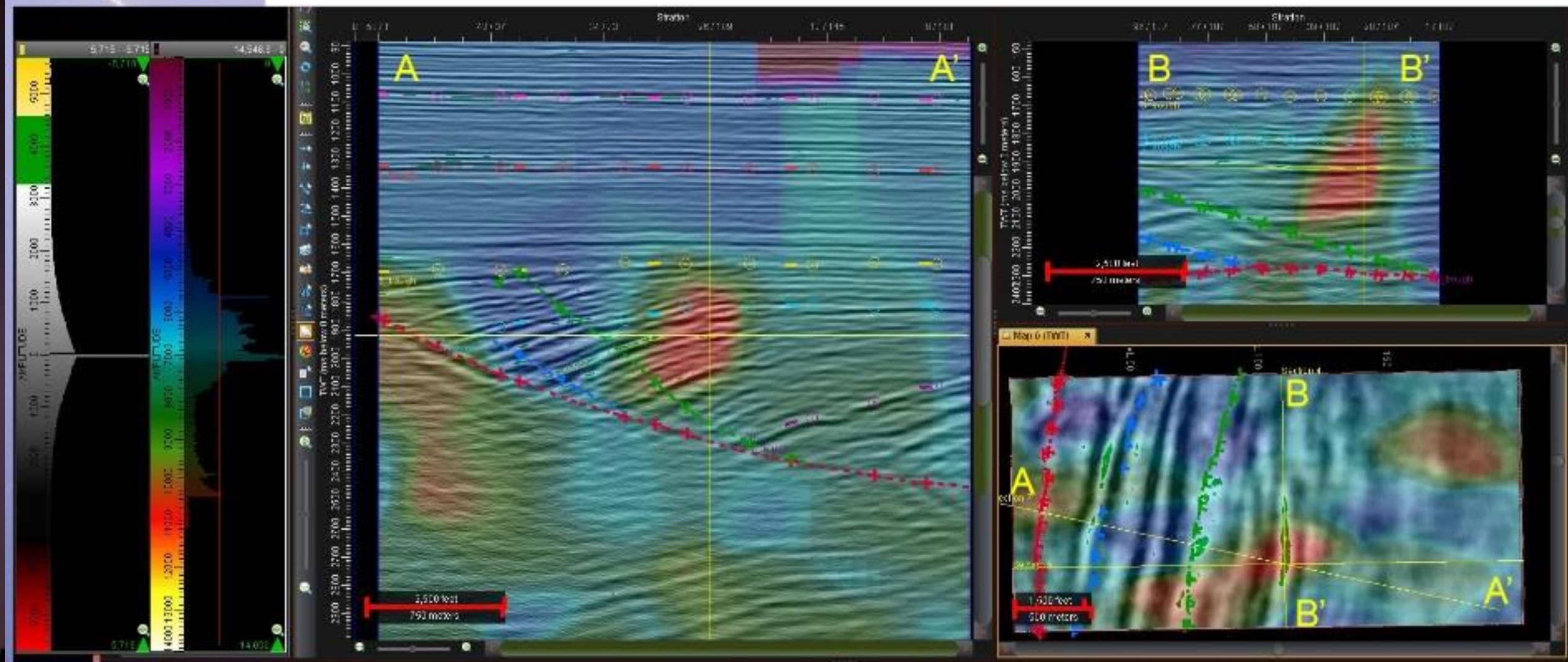
• • •

Mary Broussard
2013-2014 GCAGS President
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See updates at:

GCAGS Houston
SEG New Orleans
WTGS Midland

Seismic Calibration BEG Stratton Data, South Texas



05 Jan 2016

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Bippan, et.al. 34



CGG



While we have advanced technology to the point of being able to recognize fracturing on seismic data, acquiring the large data sets necessary for this type of exploration is cost prohibitive.

Lightning data on the other hand is comparatively inexpensive and if it can be used in a way to focus seismic dollars to imaging the targets, then the savings from smaller focused 3-D seismic data sets makes this money well spent.

Lightning, A Shockingly Unconventional Way to Conduct Exploration



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