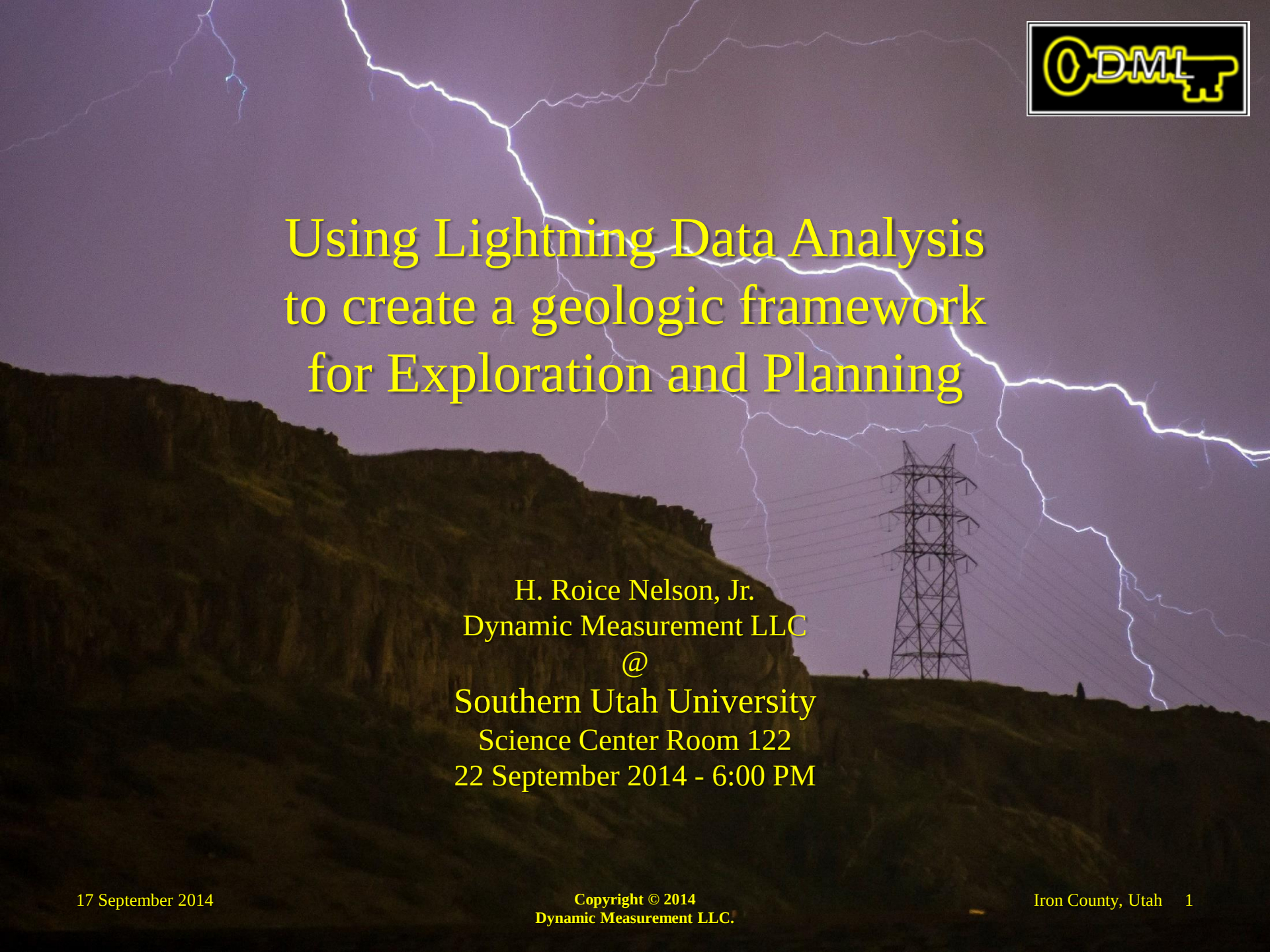

Using Lightning Data Analysis to create a geologic framework for Exploration and Planning

H. Roice Nelson, Jr.
Dynamic Measurement LLC
@
Southern Utah University
Science Center Room 122
22 September 2014 - 6:00 PM

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Agenda

- Introduction
- Lightning Data Analysis
- Resistivity Volumes
- Geologic Frameworks
- Exploration for Hydrocarbons
- Exploration for Minerals
- Planning for Water Conservation
- Planning for Development
- Plans

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Introduction – Dad's farm in 2014

- I grew up on the back-end of a shovel on The Star Ship Enterprise.
- In 1970 Ray Gardner and I started a new city plan conversation.
- In the 1980's Landmark Graphics changed oil & gas exploration.
- We continue to make a difference, data mining lightning databases.

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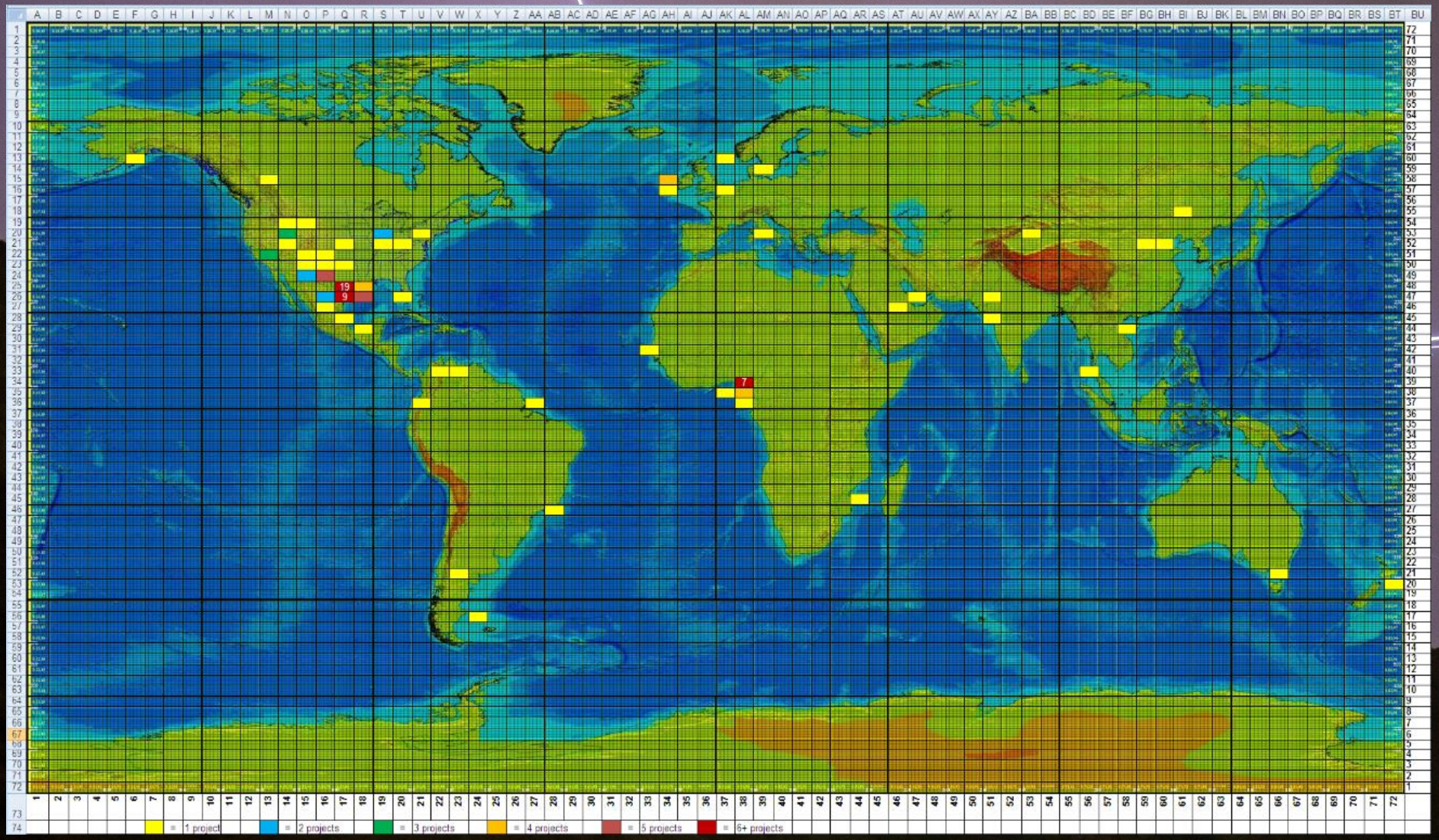
HRN Seismic Interpretation Projects:



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Serial Entrepreneur:

- The Keynotes & They Mydknight Hour
- Computer Genealogical Services
- Allied Geophysical Laboratories
- Landmark Graphics Corporation
- Global Basin Research Network
- China Cattle Corporation
- Walden 3-D, Inc.
- Dynamic Oil & Gas Corporation
- Advanced Structures, Inc.
- HyperMedia Corporation
- Walden Visualization Systems
- Continuum Resources International Corporation
- Dynamic Resources Corporation
- Dynamic Measurement LLC

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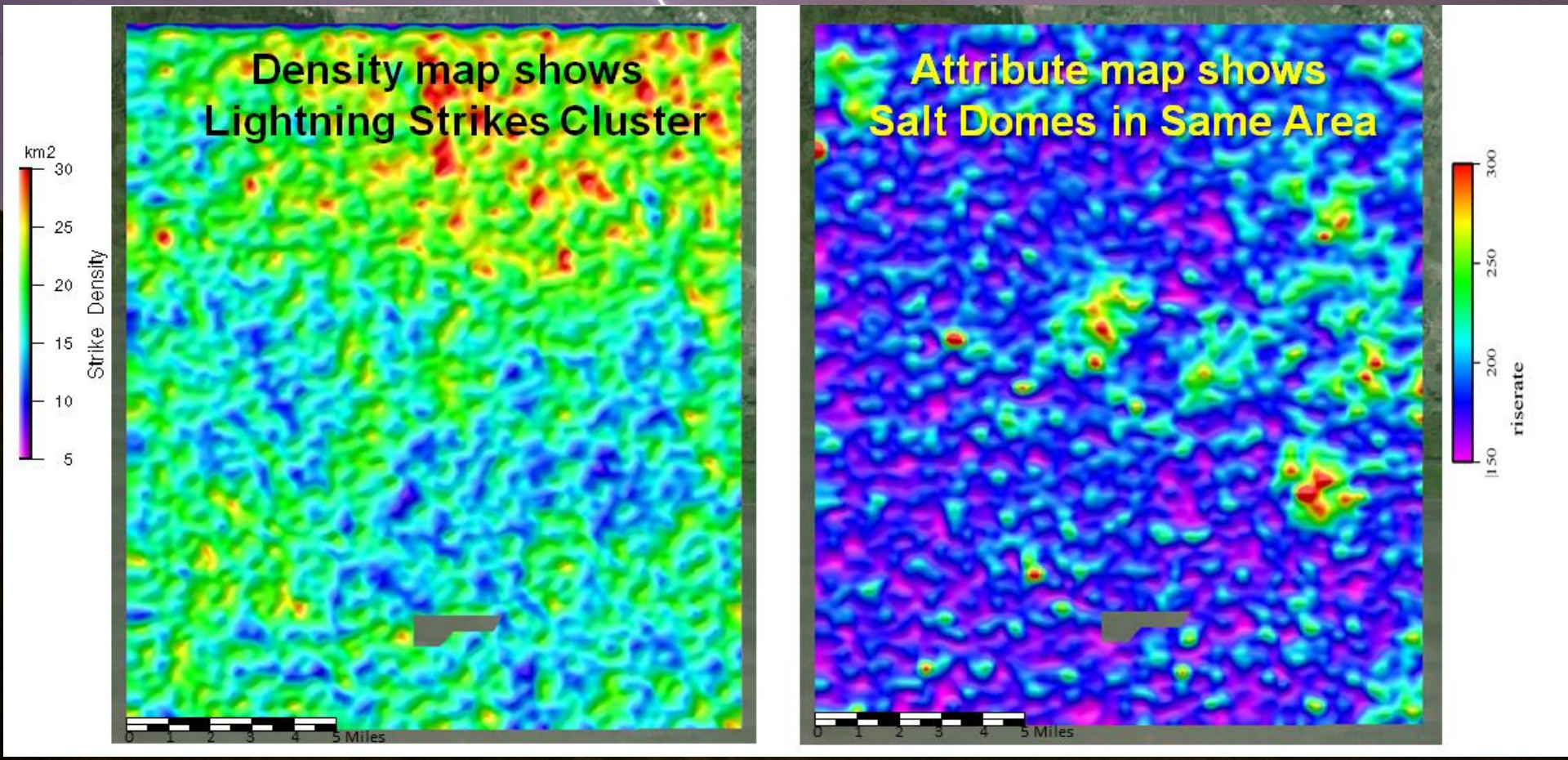
Lightning Data Analysis



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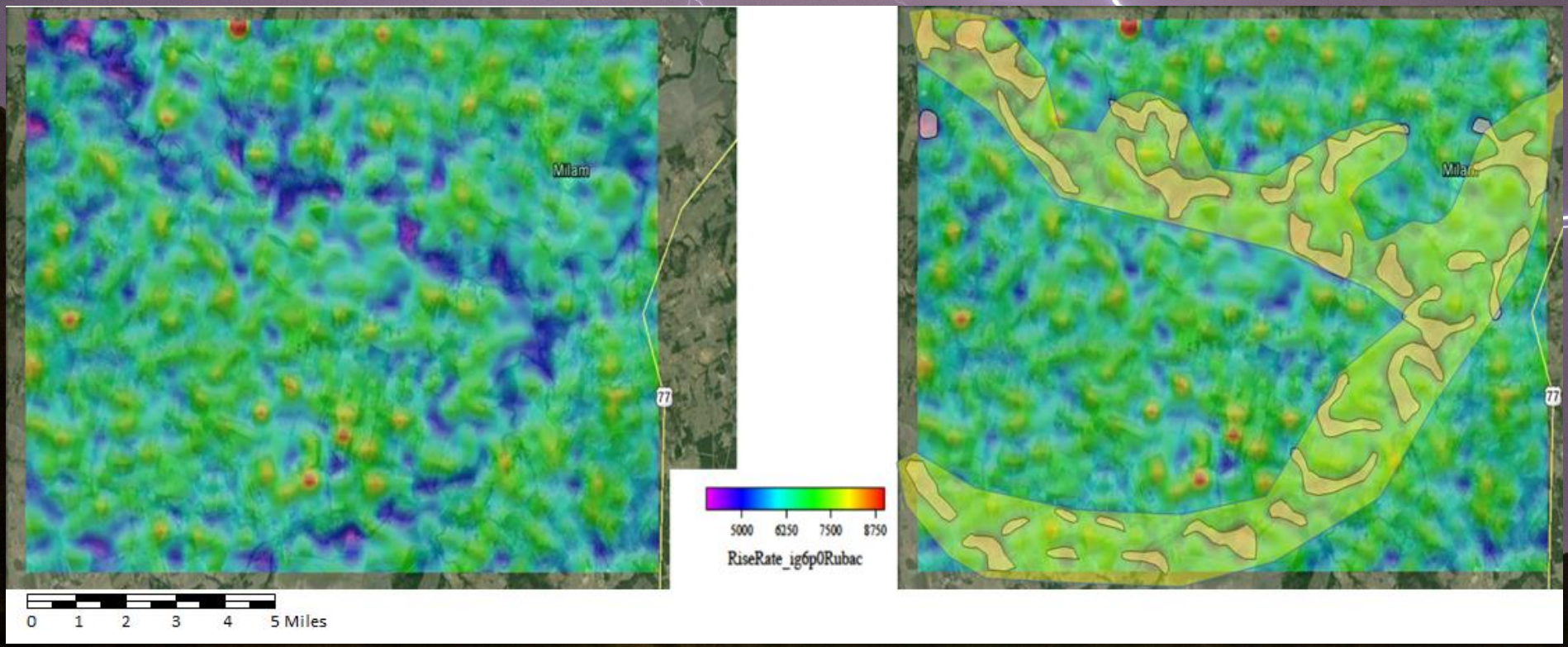
Lightning Analysis Defines Stratigraphy



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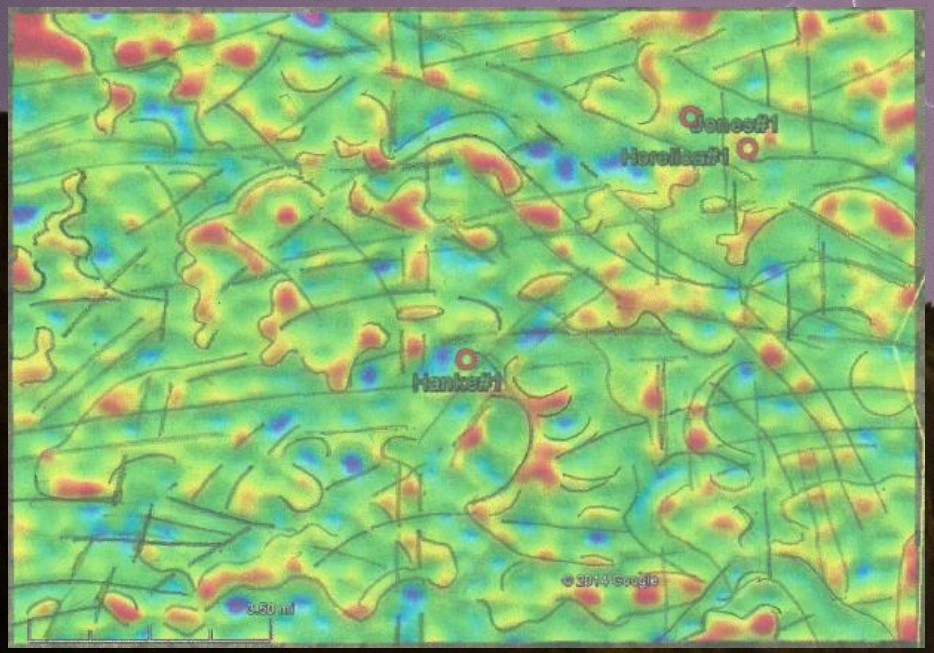
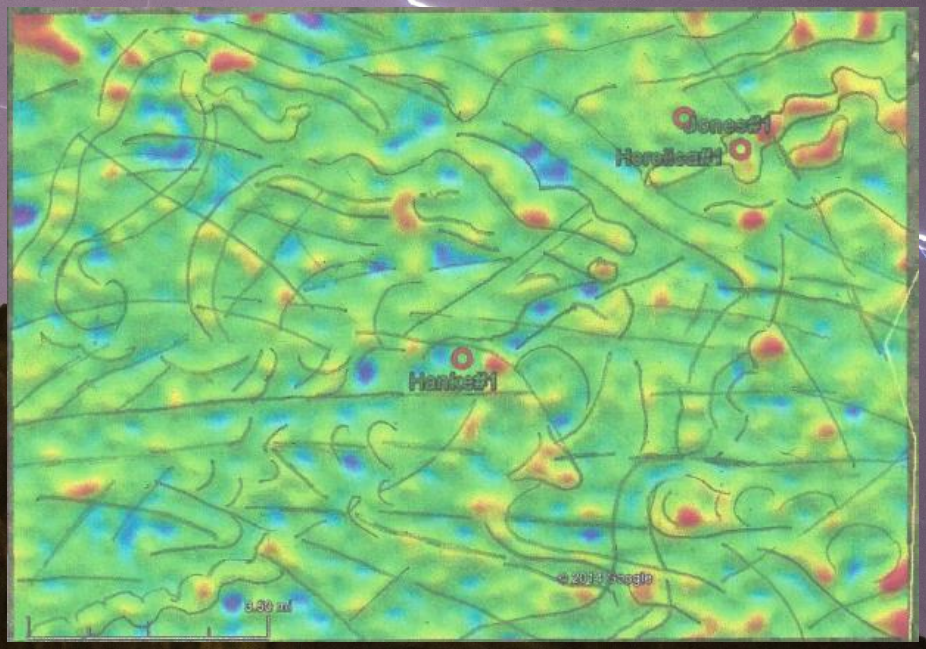
Lightning Attributes like Surface Resistivity and Peak-to-Zero show paleochannels and meander schrolls





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A Texas Duck Hunting Story

1. Hunting Ducks on property adjacent to the Hockley Salt Dome when Joe watched a storm come up, wrap around the edge of the dome, and a lightning bolt came down not far from where he was parked in his truck.

2. Back at the same place, parked in the same spot a year later, when exactly the same thing happened again. Drove to Roice's house and asked: "Does lightning strike twice in the same place?"

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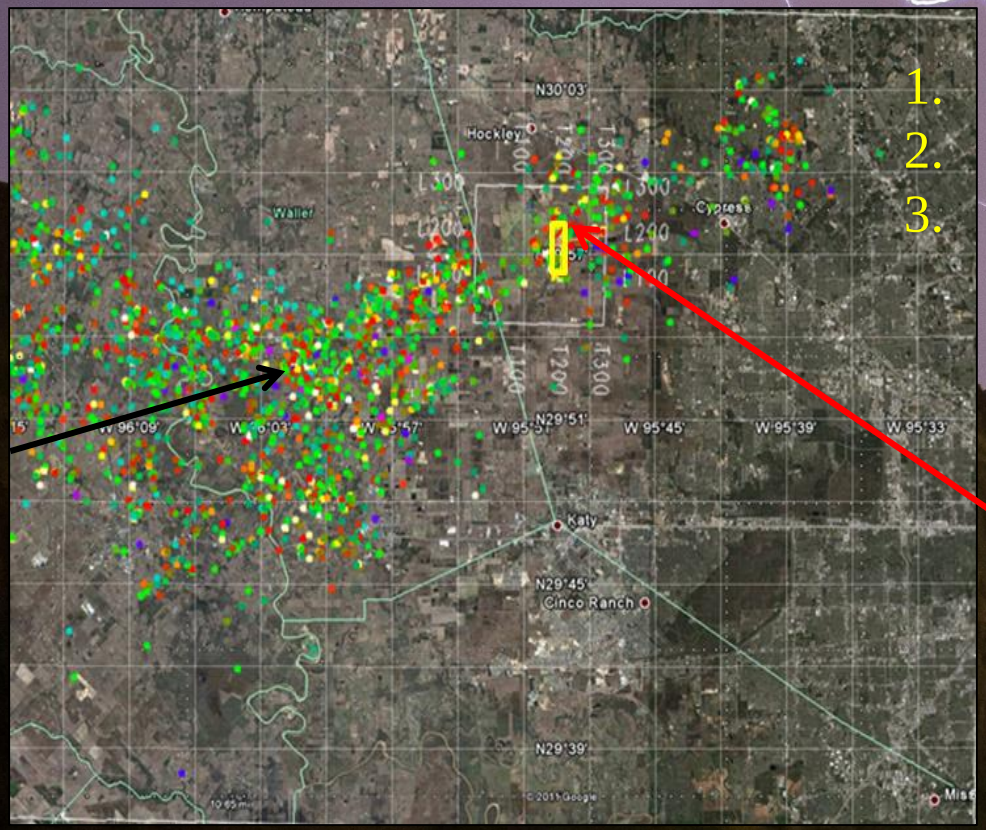
A Texas Duck Hunting Story continued



1.
2.
3.

On the 27th of September 2011, back at the same place, Joe saw a spectacular lightning storm:

- the storm came from the west (black arrow);
- Joe was parked at the north of his property; &
- it appeared to him like the world was on fire all around him.

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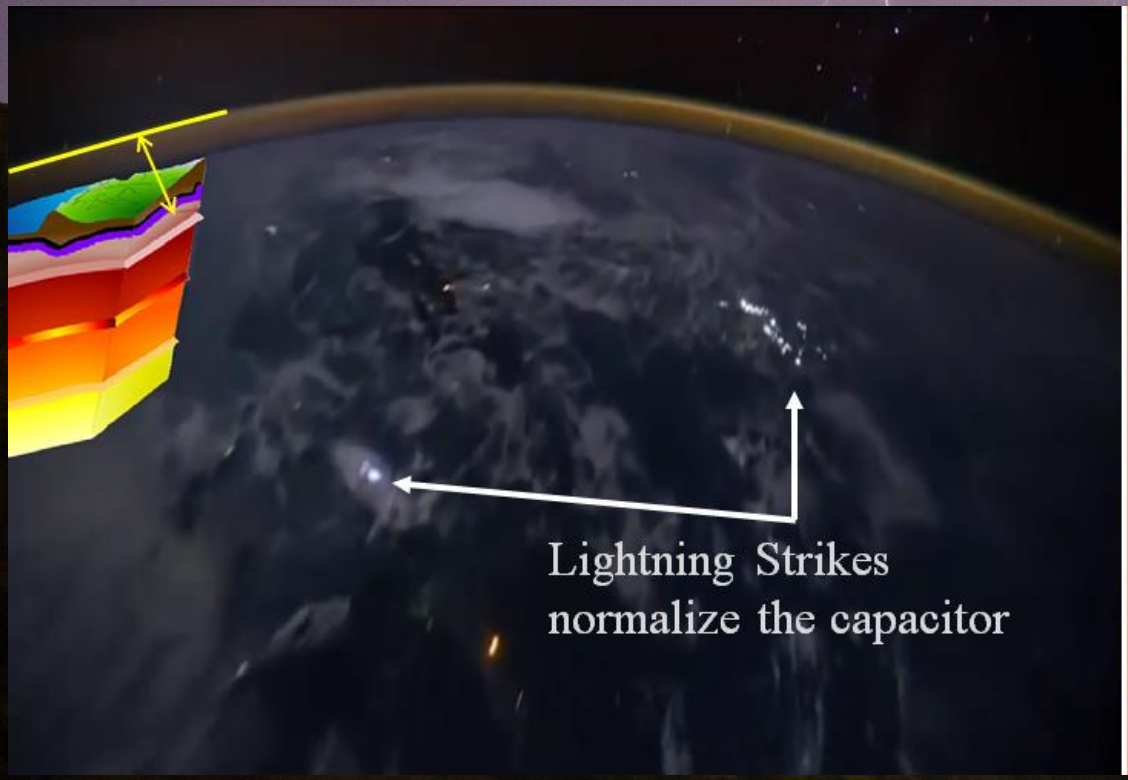
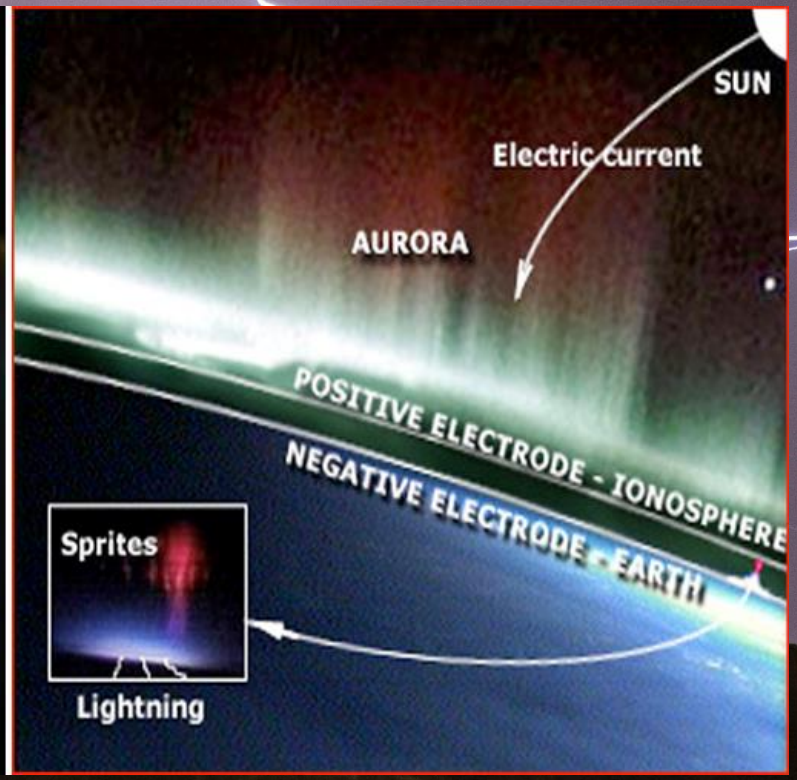
Earth's Electrical Field
A Self-Repairing Capacitor





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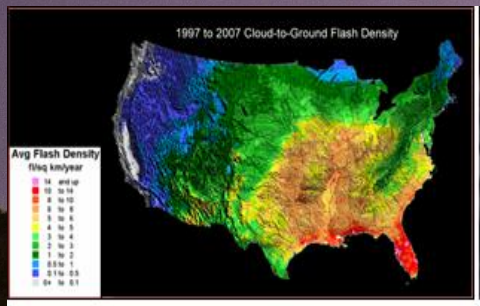
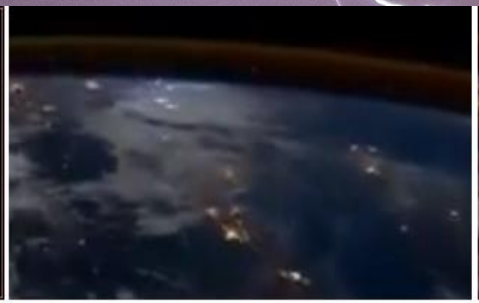
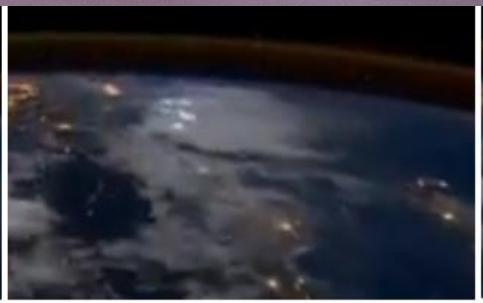
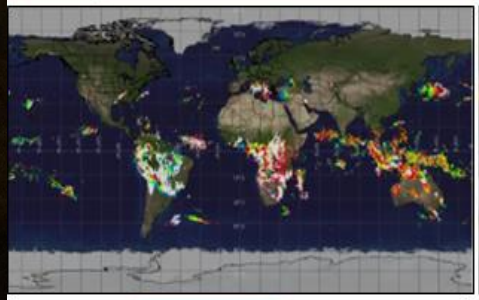
Lightning Occurs Everywhere
and is in public and private databases









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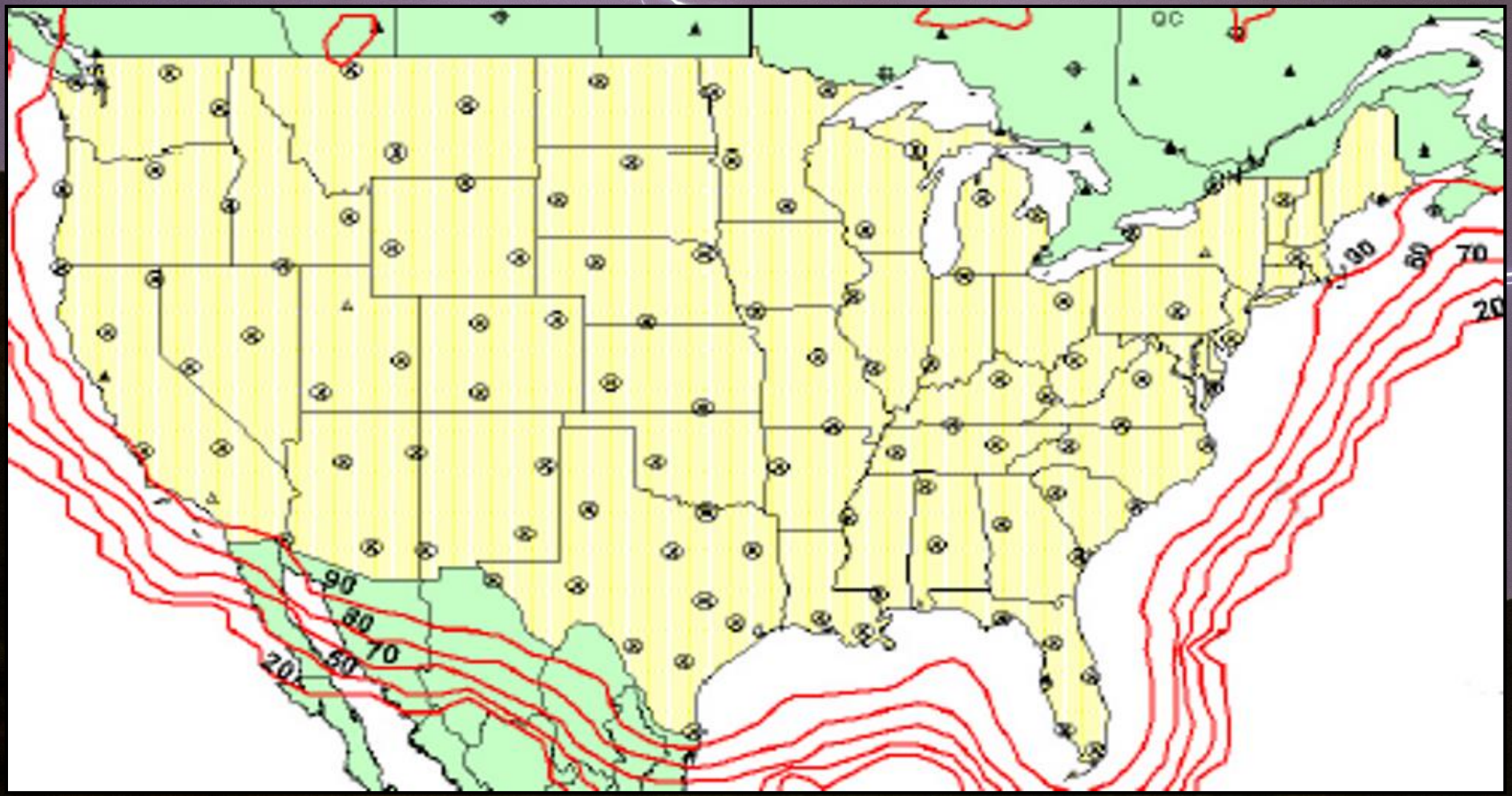
NLDN:
National Lightning Detection Network



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Lightning recorded for early storm warning, safety, **insurance**, and meteorological purposes

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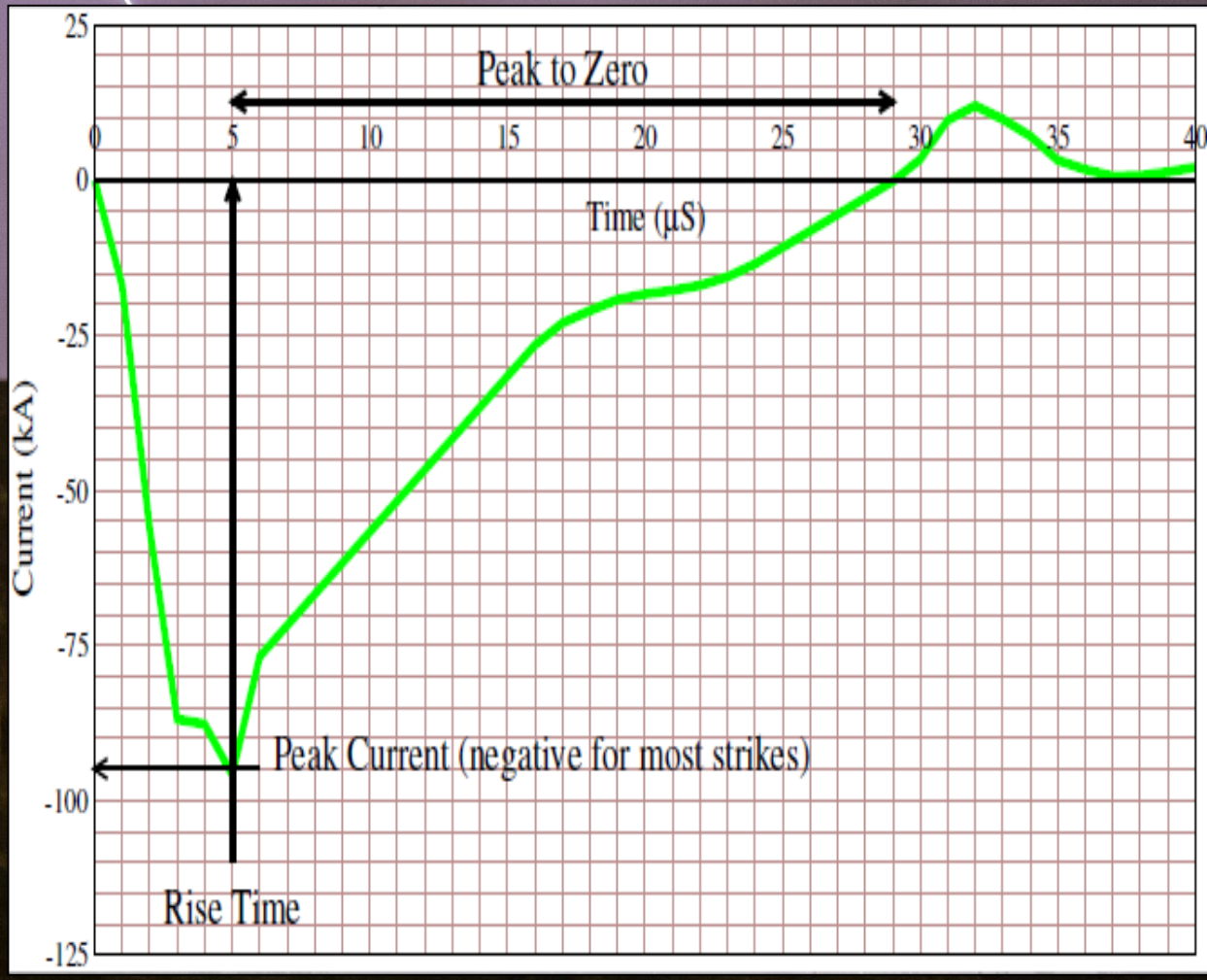
Lightning Strike Waveform

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



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Proven and 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)

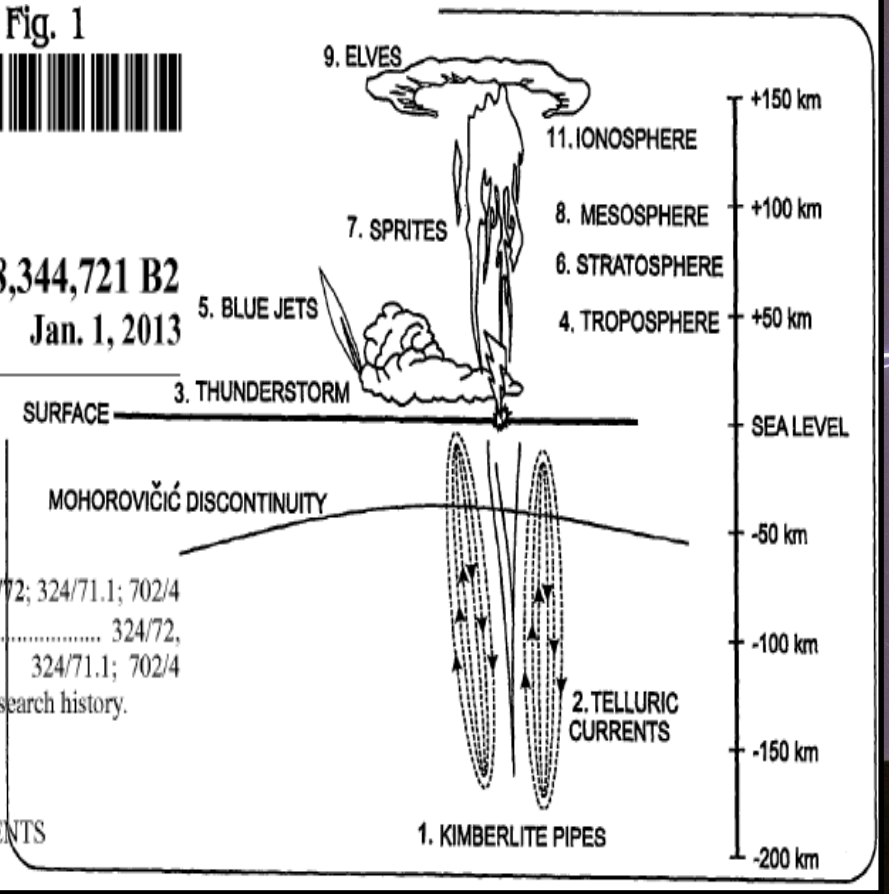
(52) **U.S. Cl.** **324/72**; 324/71.1; 702/4

(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



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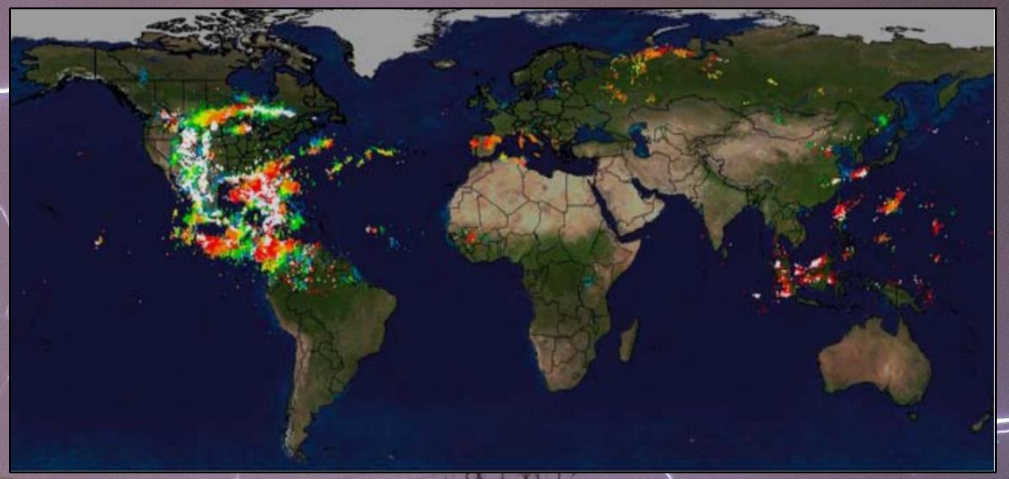
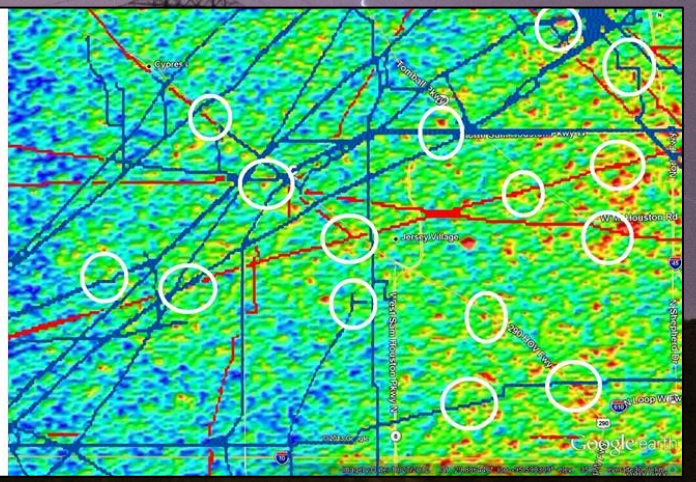
Vaisala and Wipro Partnerships

- Exclusive worldwide license with Vaisala of Finland to use their data in the NLDN and GLD-360 for natural resource exploration.



- Agreement with Wipro to clean, process, and handle lightning data according to DML specifications



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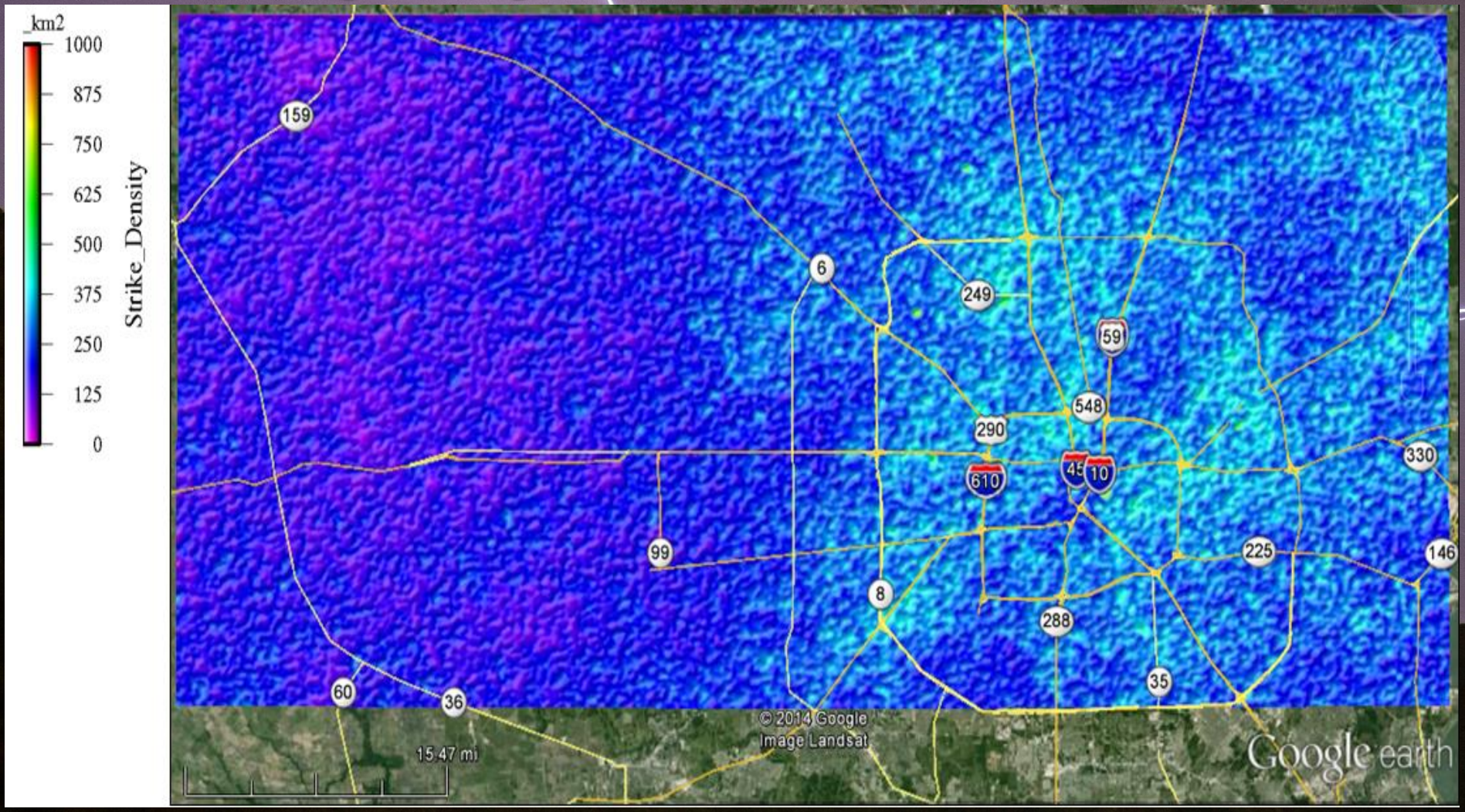
Density Map Shows Lightning Strikes Cluster



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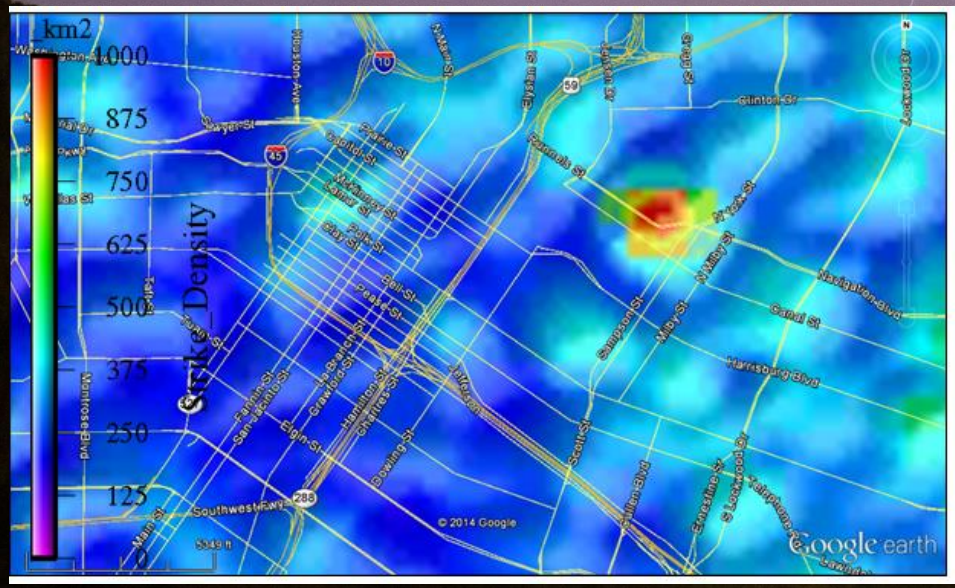
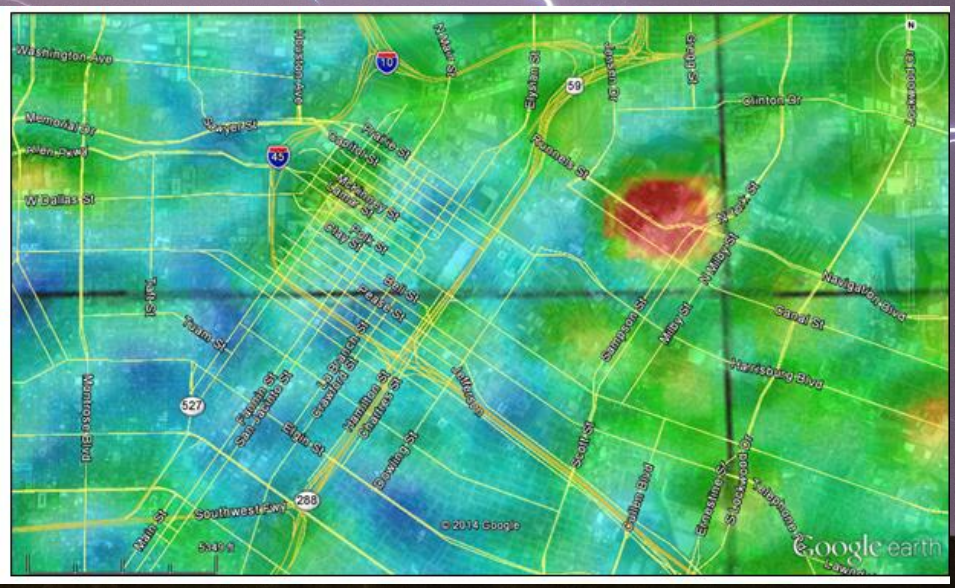
Clusters Skew Density Map Color; Normalization Improves Displays





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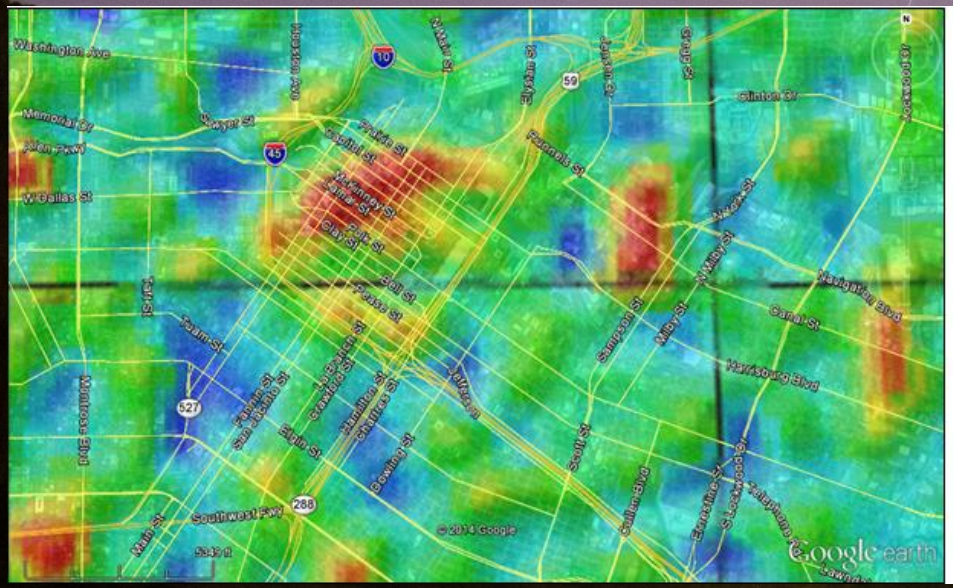
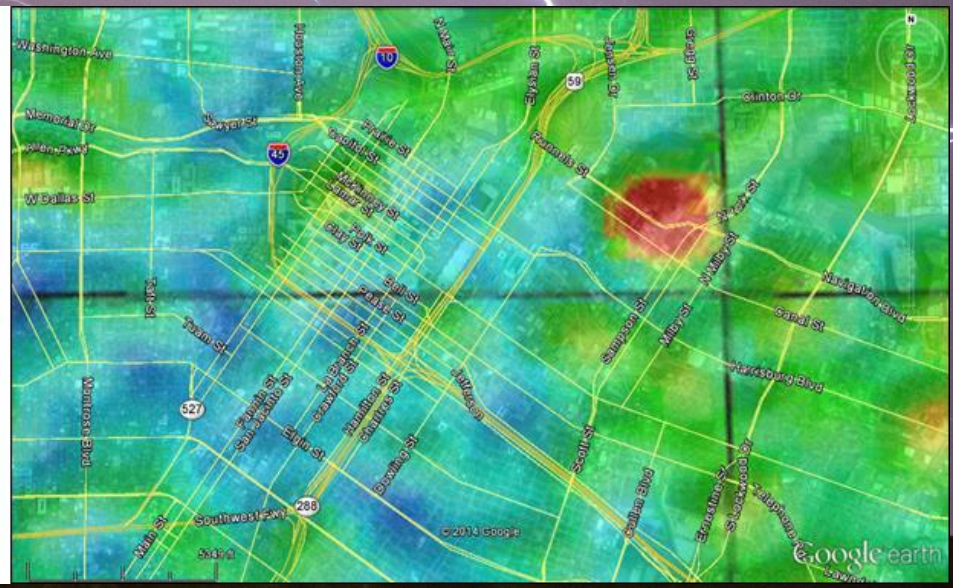
Average Negative Peak Current vs. Density





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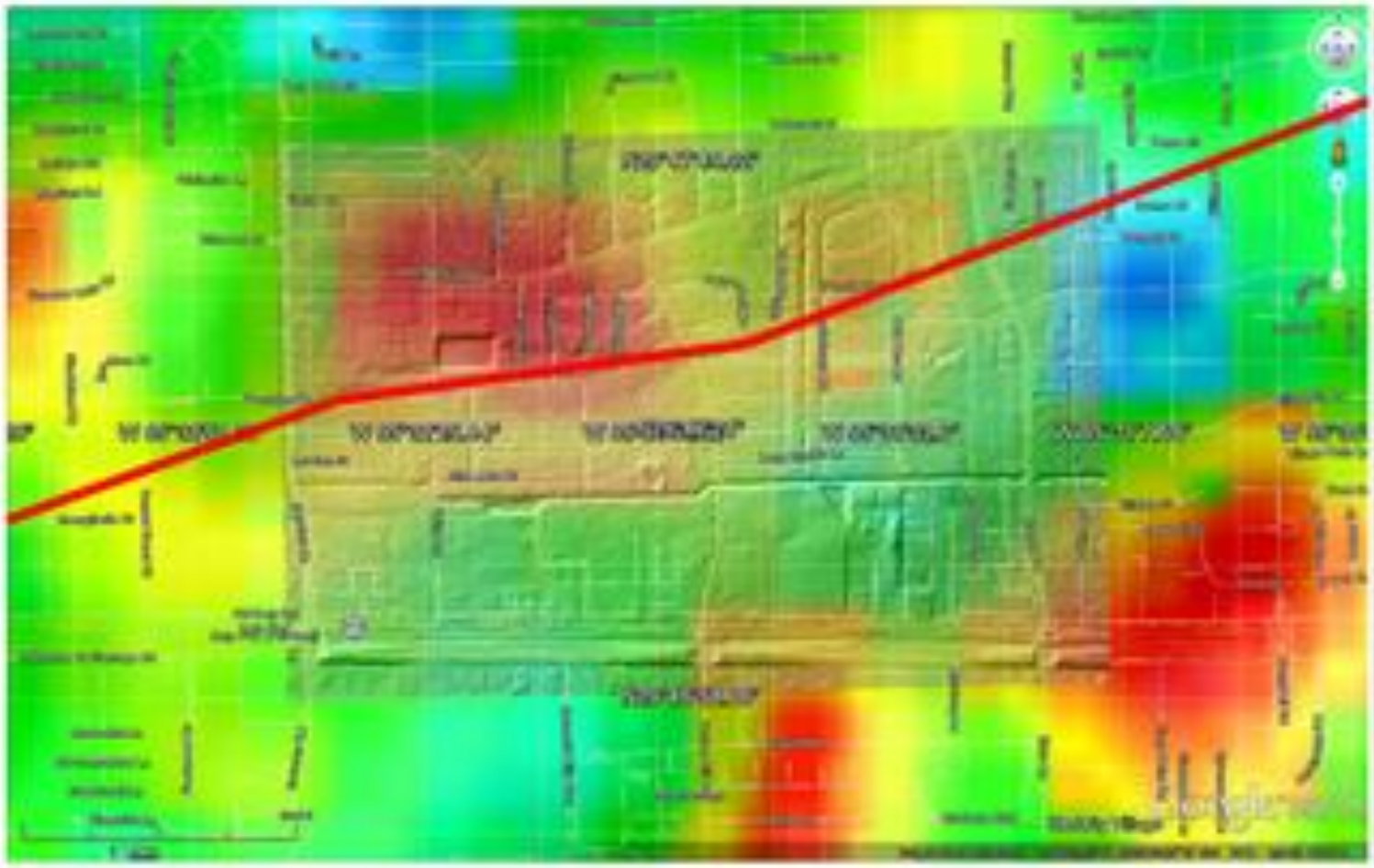
Peak Current Zoom with LIDAR & Long Point Fault



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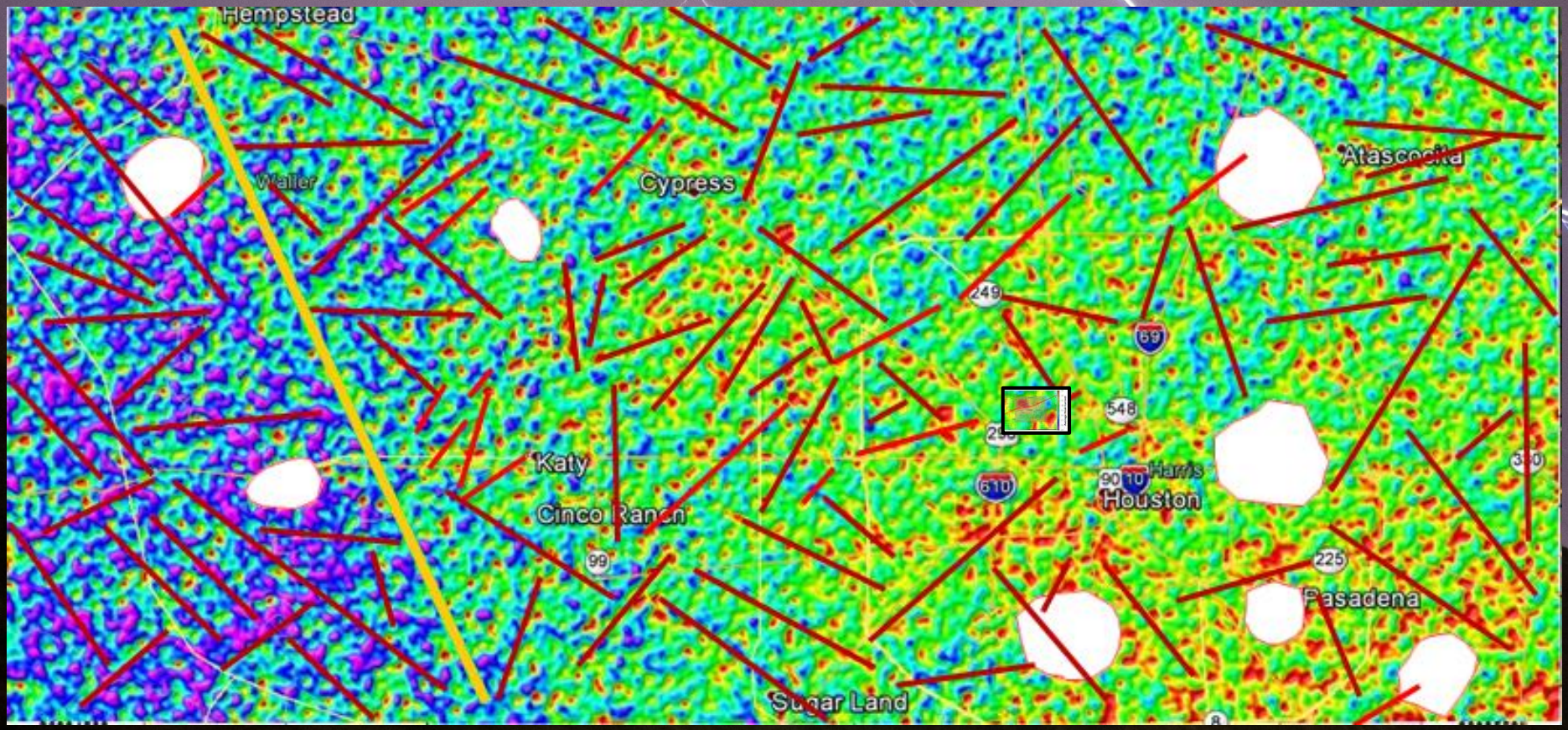
Peak Current from Sealy to East Houston



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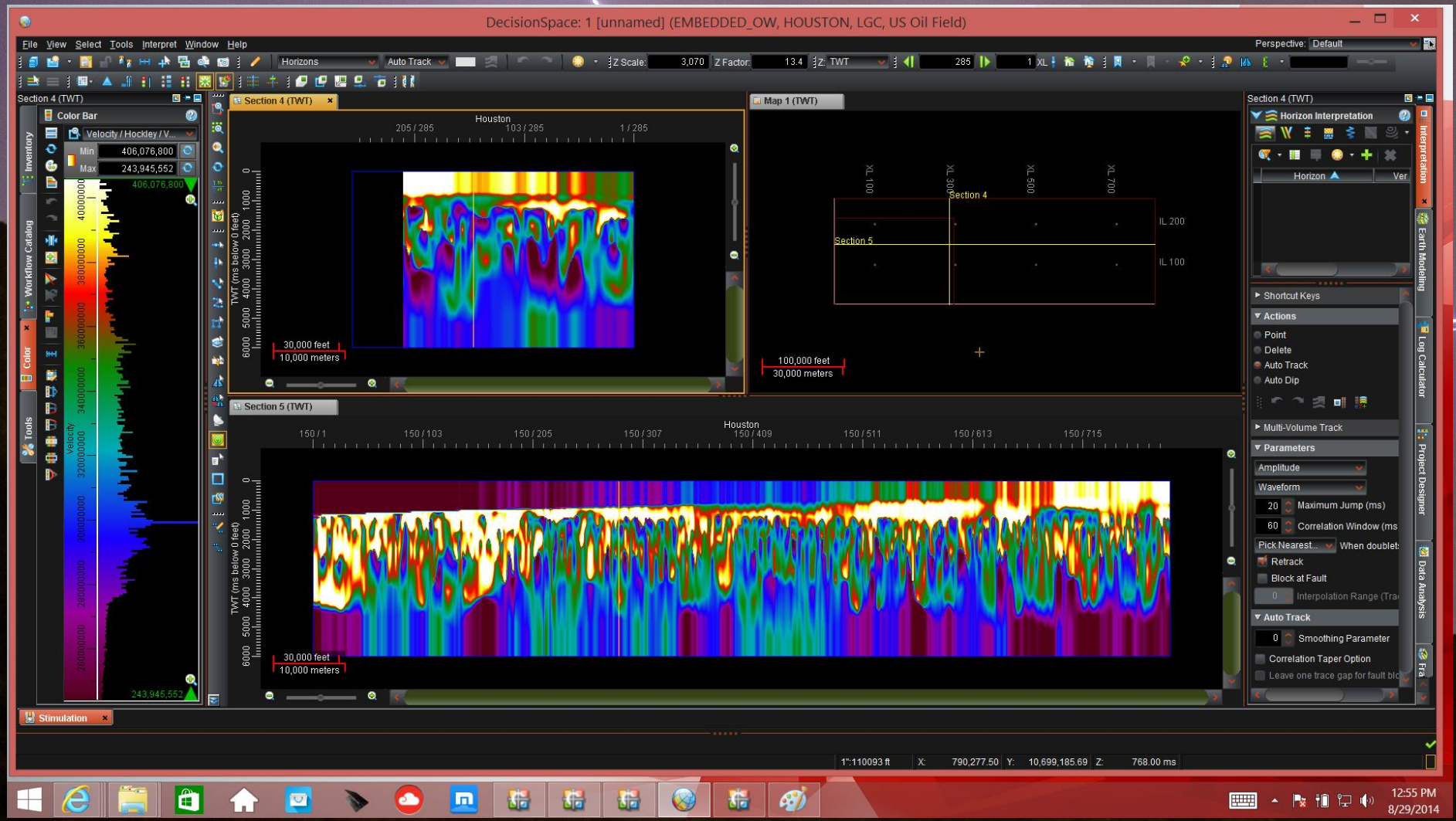
Resistivity Volume
Sealy to East Houston



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Resistivity Volumes

- Archived lightning databases can be used to:
  - Generate Resistivity Volumes.
  - Interpret with Seismic Interpretation Systems.
  - Integrate with conventional 2-D or 3-D seismic surveys.
  - Correlate with well log data.
  - Interpret geology and things like hydrocarbon migration pathways.

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Recorded Lightning Data

- Cloud-to-ground lightning can be measured and recorded
- Lightning measurements have been made for more than thirty years
- A continuous record of essentially all cloud-to-ground lightning strokes in the contiguous U.S.A. and Canada has been made for approximately fifteen years.
- A continuous record of cloud-to-ground lightning strokes worldwide has been made for about four years

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Plate 1

The Atmospheric Capacitor

- The charged thundercloud is one plate of a capacitor
- The other plate of the capacitor is the earth underlying the charged cloud
- The dielectric is the air
- Energy from a lightning strike is converted to heat, partly in the air, but largely in the subsurface

Dieletric

Plate 2

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Lightning a Dielectric Breakdown

- Lightning occurs when the voltage across the atmospheric capacitor exceeds the dielectric strength of the air.
- Resistance in the atmosphere is very low once the path is ionized.
- Resistance in the subsurface is approximately constant over long periods of time.
- Atmospheric factors vary with each stroke.

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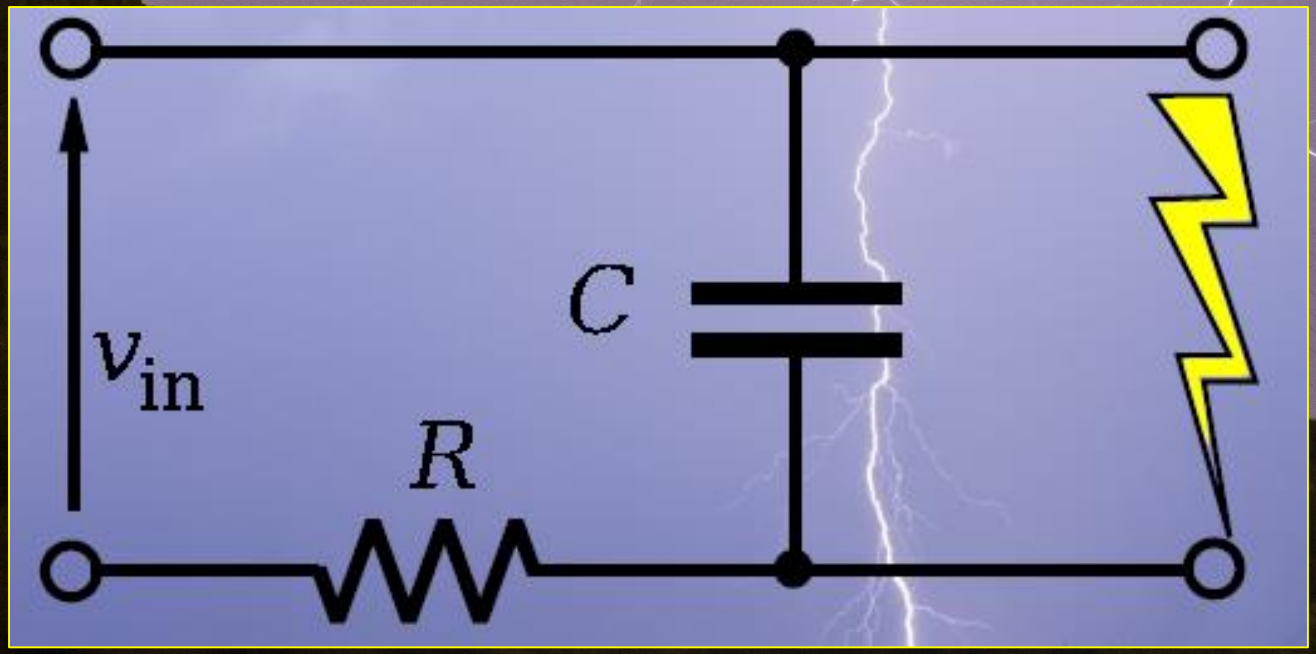
Relaxation Oxcillator

- The physics of lightning discharge are similar to the physics of a neon-tube relaxation oscillator.
- In each case, voltage builds across a capacitor until an insulating gas ionizes and becomes a conductor



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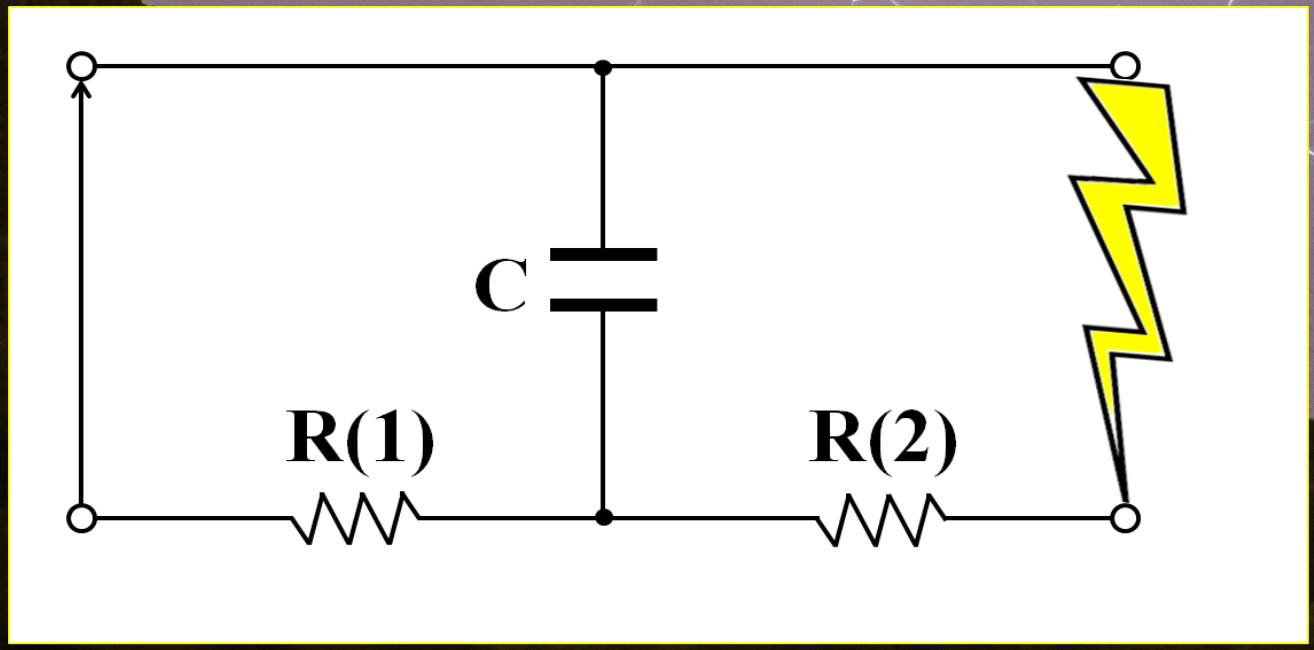
Lightning Physics

- The atmospheric capacitor is nearly the same
- Just an additional resistance (R2) limiting the current
- R2 is the resistance between the lightning strike point and the bottom plate of the capacitor



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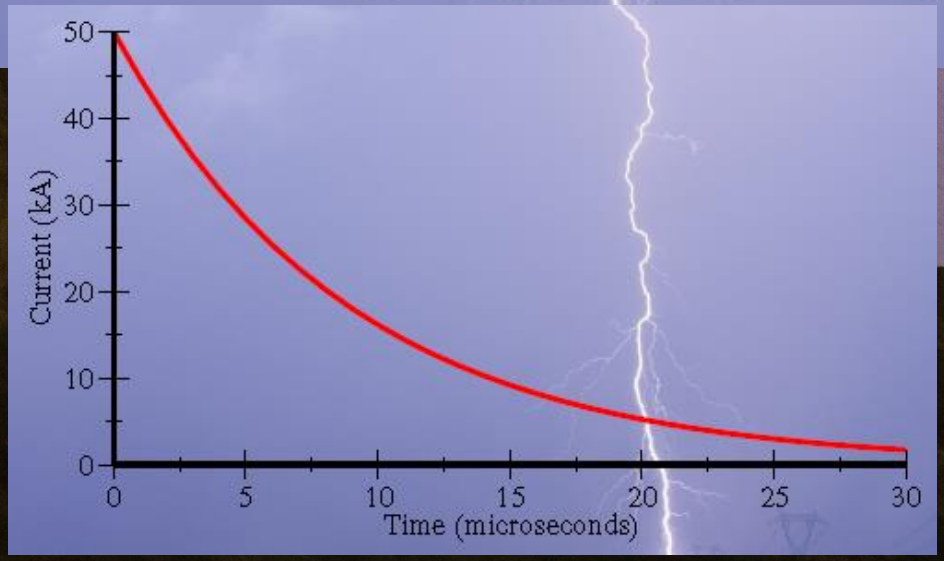
Relaxation Oscillator Physics

- When a relaxation oscillator triggers, the discharge current decays exponentially
- The rate of decay is given by $I_t = I_0 e^{-t/RC}$
- If lightning is similar, can we use the decay to measure resistance?
  - This equation can be rearranged to $ln(\frac{I_t}{I_0}) = -\frac{t}{RC}$ or $R = -\frac{t}{ln(\frac{I_t}{I_0})C}$
  - All we need is the current at two times (I_0 and I_t), and the capacitance (C) to get the resistance R



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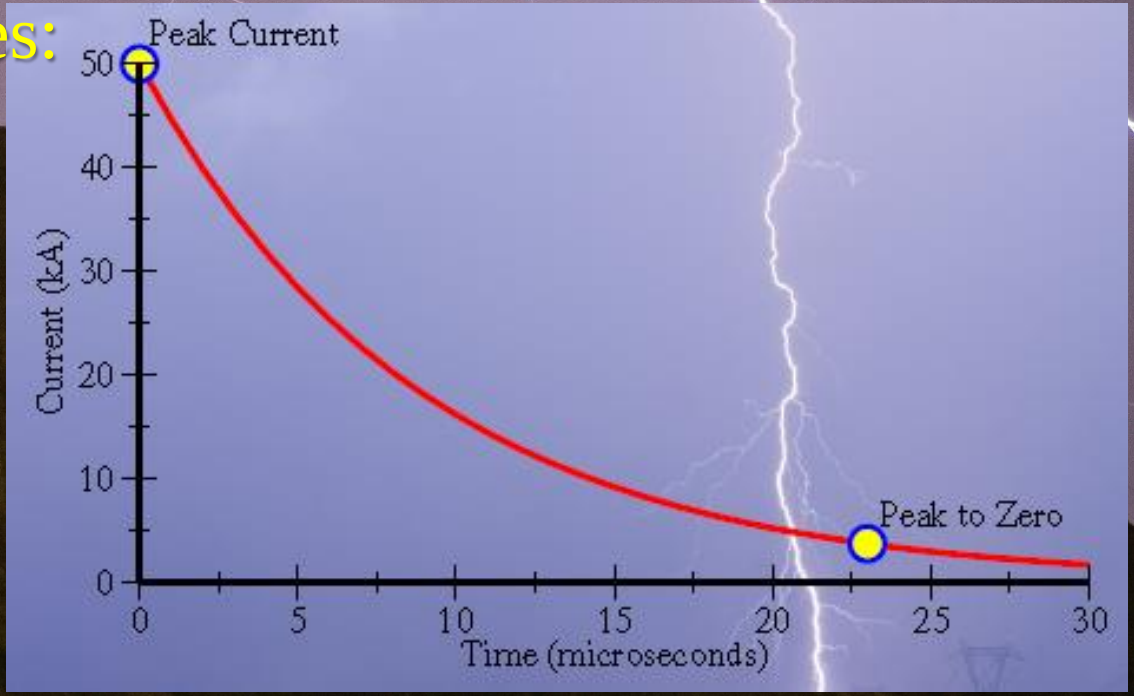
How do we measure Decay

- Lightning measurements do not give this kind of continuous decay.
- We have two values:
  - Peak current
  - Peak to zero time



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The Available Measurements

- Two points on an exponential curve will define the curve

Peak Current:

- The maximum recorded current, when decay starts (I_0)

Peak-to-Zero time:

- The elapsed time from the instant of Peak Current until the recorded signal disappears into the background noise.
- This gives us the time *t*.
- But what is the current (I_t)?
- The time for current to decay to a real zero is infinite.
- We need an estimate of the magnitude of the "zero" current (at time *t*) in order to compute resistance.

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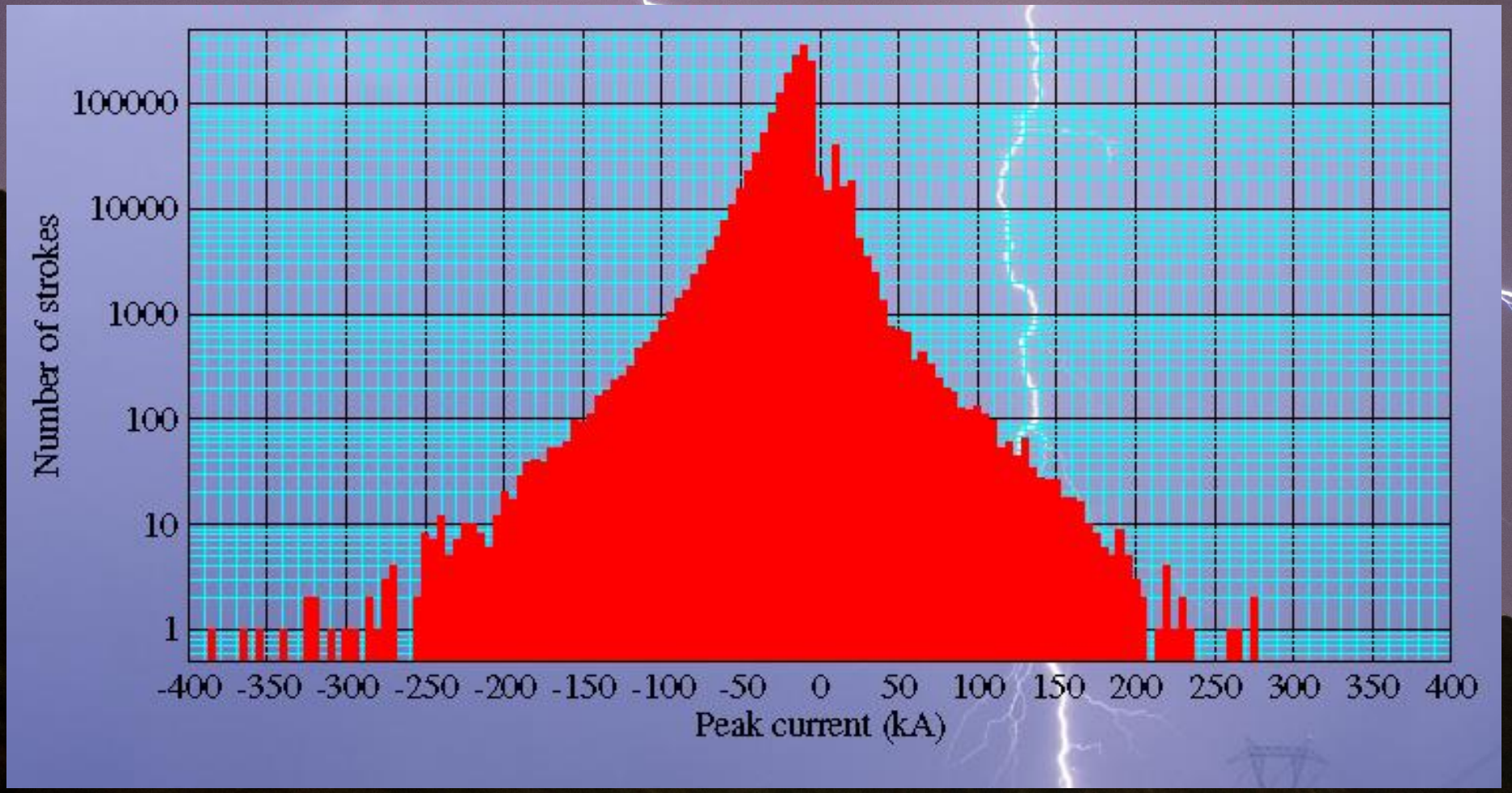
What is "Zero" Current?

Histogram of peak current for 1.6 million strikes



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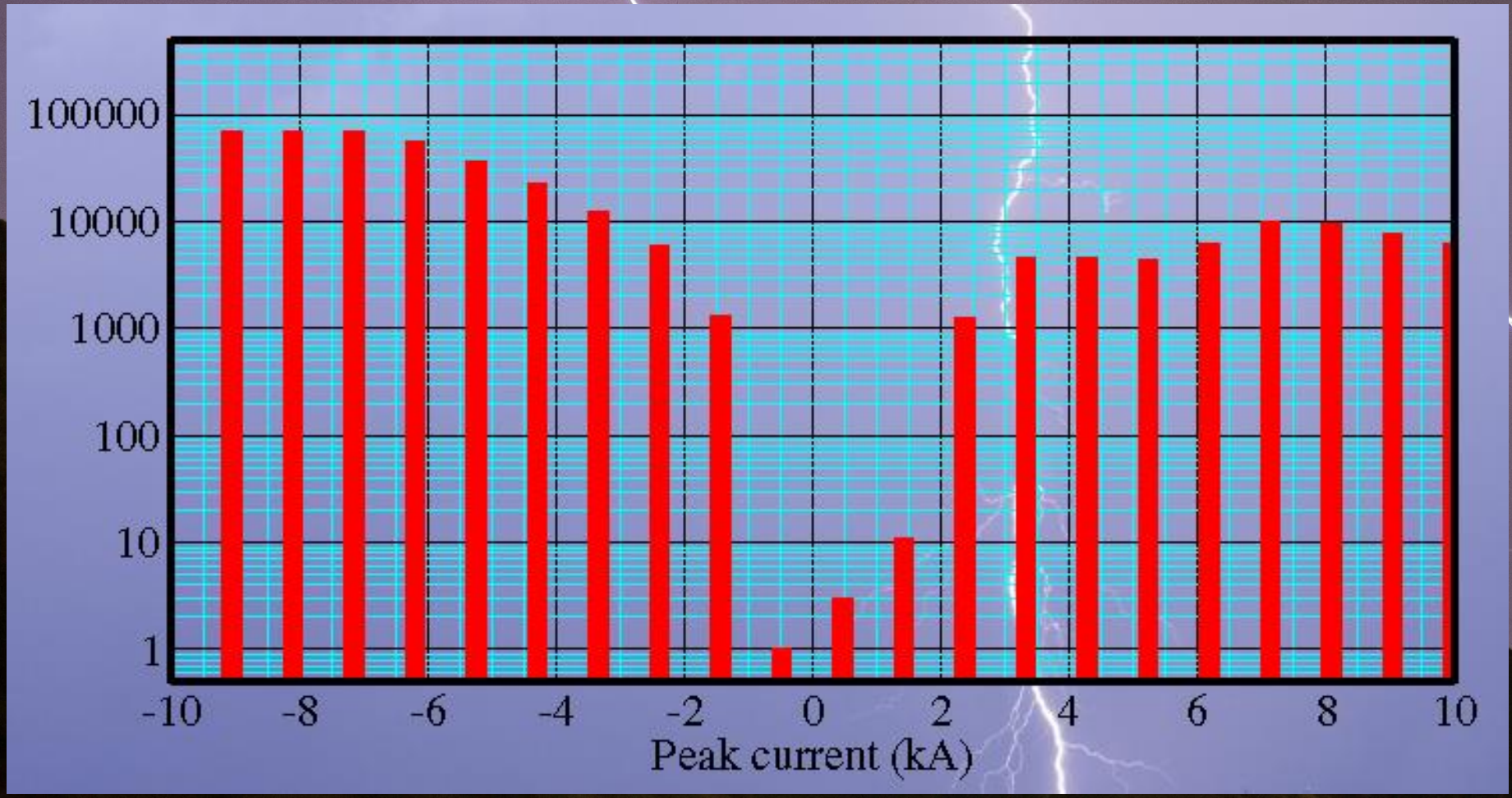
What is Zero Current?



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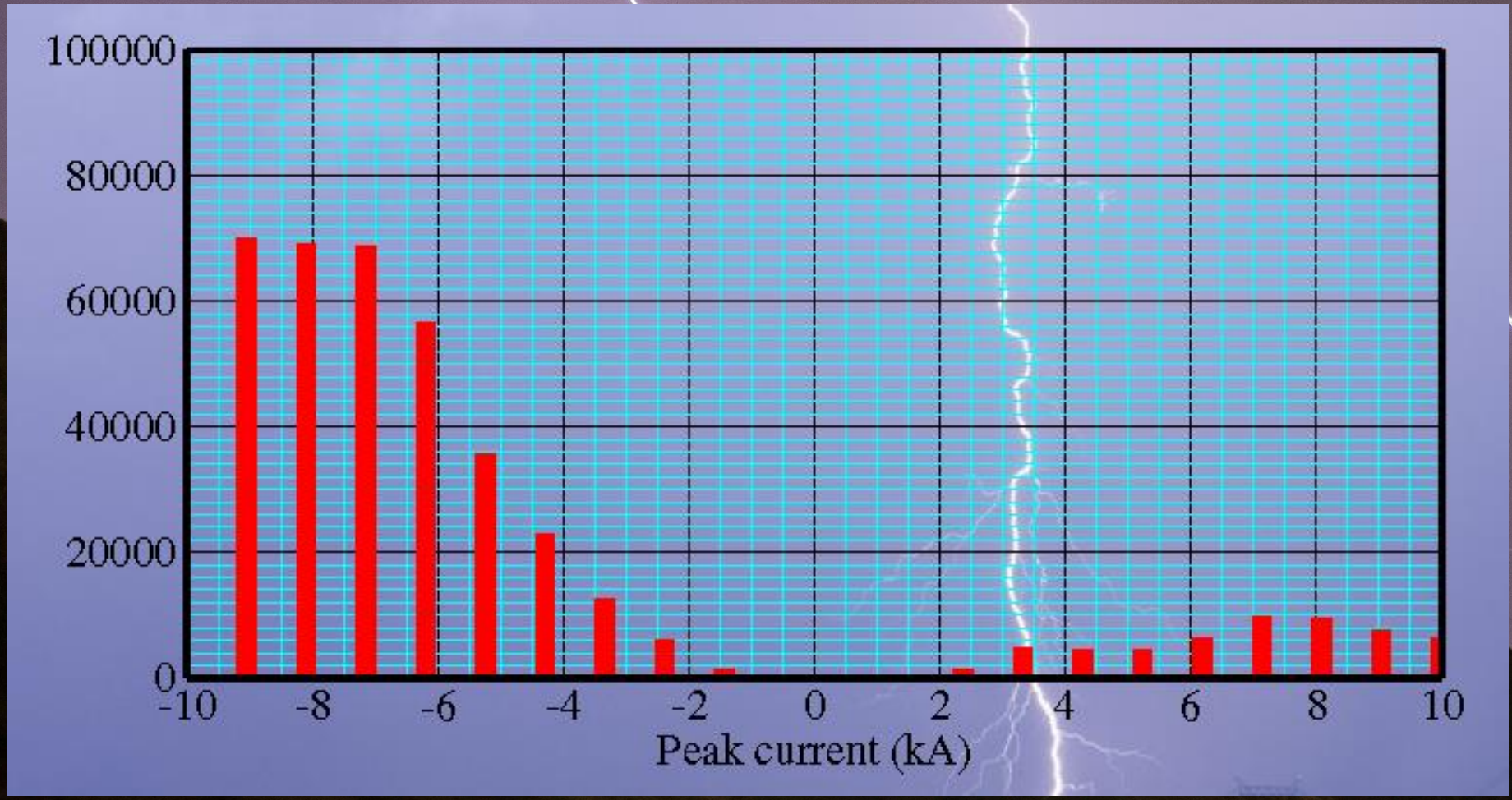
What is Zero Current?



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What is Zero Current?

- Total strikes 1.6 million
- 320,000 less than 10 kA absolute peak current
- 30,400 less than 5 kA absolute peak current
- 13,260 less than 4 kA absolute peak current
- 2,579 less than 3 kA absolute peak current
- 15 less than 2 kA absolute peak current
- “Zero” current assumed to be 1 kA

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What About Voltage?

- Resistance is equal to voltage/current.
- Our measurements are of current only.
- But the equation gives a solution with capacitance rather than voltage.
- However, how do we find capacitance?
- Capacitance depends on permittivity, plate area, and plate separation.
- While permittivity is approximately constant and known for air, assumptions for area and separation are needed to solve for resistance.

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The Assumptions

1. Voltage is proportional to peak current (within a local area).
2. Cloud height is proportional to voltage because the dielectric strength of air is more or less constant.
   - This gives plate separation for the atmospheric capacitor
3. The effective capacitor is circular, with a radius proportional to cloud height.
   - This gives plate area for the capacitor
4. With over 100 lightning strikes per square kilometer per year in many areas, we can stack results to improve signal-to-noise ratio

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What is Resistivity?

- Resistivity is resistance times cross-sectional area of a conductor, divided by its length; or $\rho = \frac{R \times A}{l}$
- For the lightning energy dissipating in the ground:
  - The area is very small at the strike point, but increases rapidly
  - The length is very short for discharging the charge close to the strike point, but for points near the edge of the effective capacitor, the length is much greater
- For low energy lightning, the resistivity measured is that of rocks close to the surface
- For higher energy lightning, the resistivity measured is an average of resistivities to greater depths.

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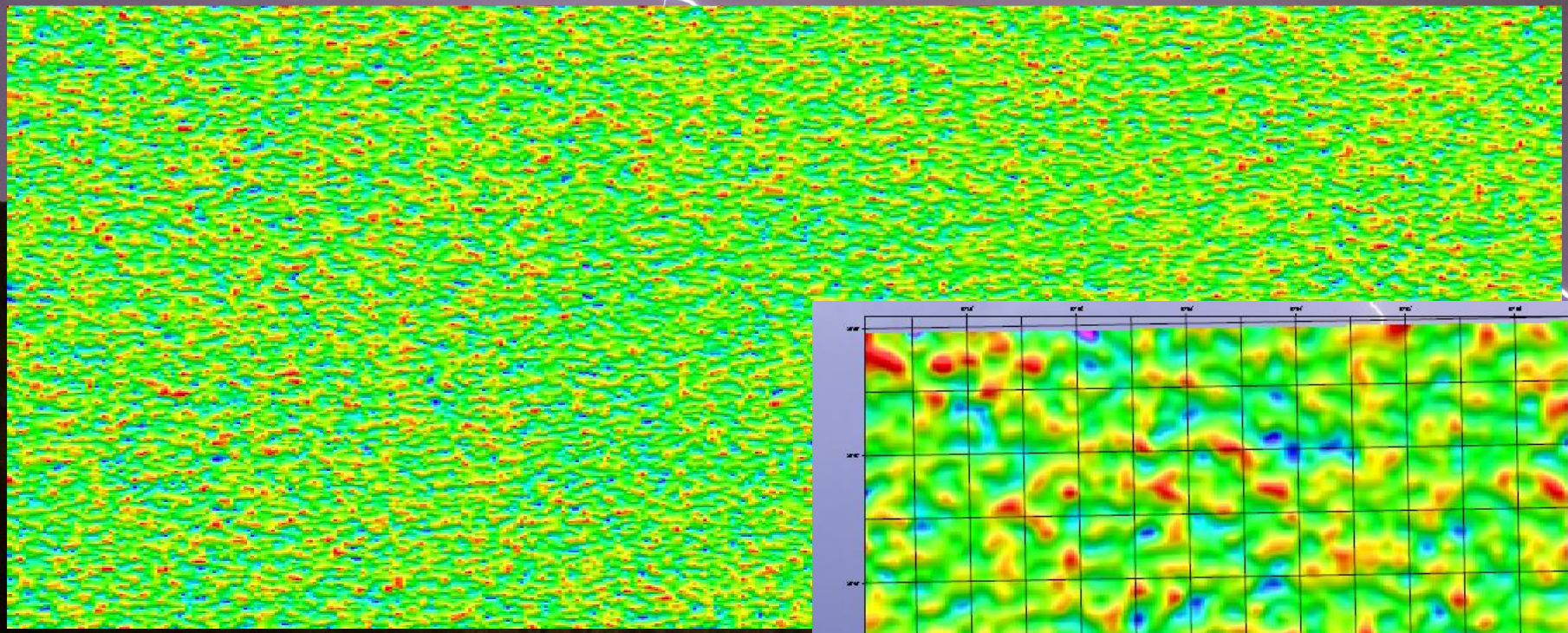
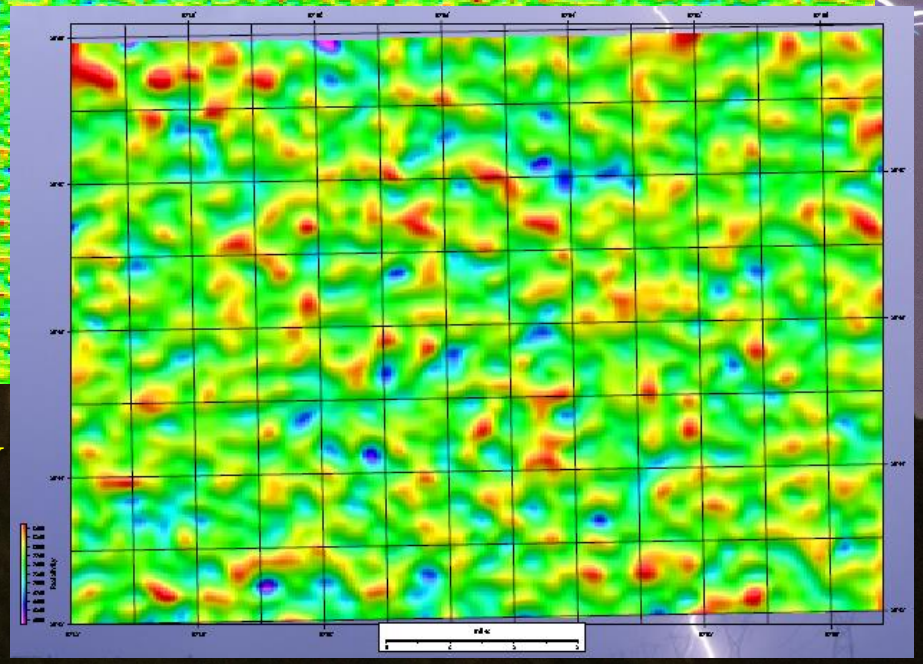
Resistivity Maps

Houston Area



Milam County



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Resistivity and Depth

- As mentioned above, electrical energy from more powerful strikes is partially dissipated at greater depths.
- So grouping strikes by peak current will give resistivities grouped by depth.

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Determining Resistivity and Depth

1. Lightning data is divided into several groups (typically 10) by absolute peak current.
2. Each peak current group is divided into small (typically 0.03-0.04 km^2) cells by latitude and longitude.
   - Not all cells will contain a lightning strike, but some cells will contain more than one lightning strike.
3. For each cell in each group, resistivity and depth values are computed from the lightning data.
4. For each group a smooth surface is fitted to the depth values and to the resistivity values.
   - At any point in the project area, a number of depth/resistivity pairs equal to the number of groups in 1 can be produced by extracting grid values at that point.

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A Resistivity Trace

- For standard seismic interpretation software, data traces need to be uniformly sampled in time or depth, with the same number of samples in each trace
  - At latitude and longitude for the trace, each depth grid is sampled and each resistivity grid is sampled.
  - Resistivity values are interpolated with depth between these points to give samples at uniform intervals.
- Typical sample interval is 48 meters.
- Typical trace length is 125 samples.
- There is no restriction in sample interval or length beyond those imposed by the SEG-Y format.

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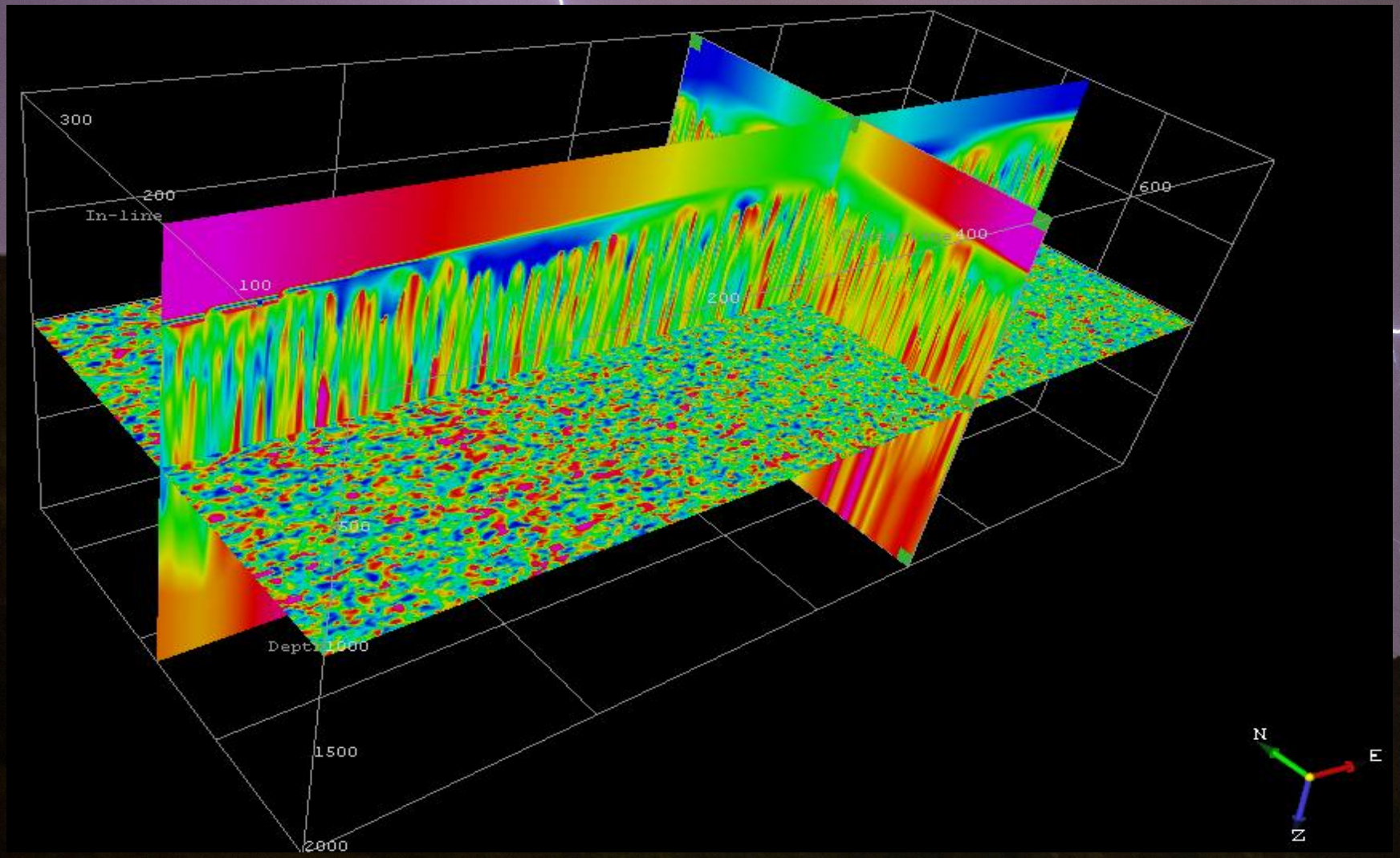
A Resistivity Volume



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A Geologic Framework

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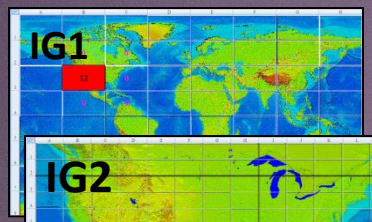
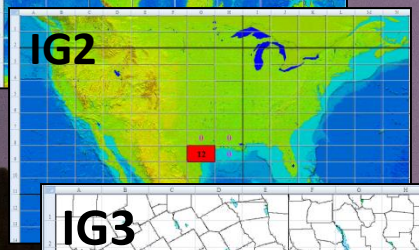
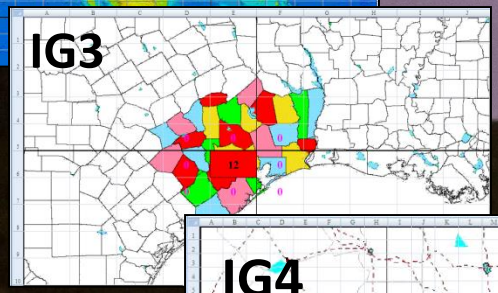
Area Based GIS Framework

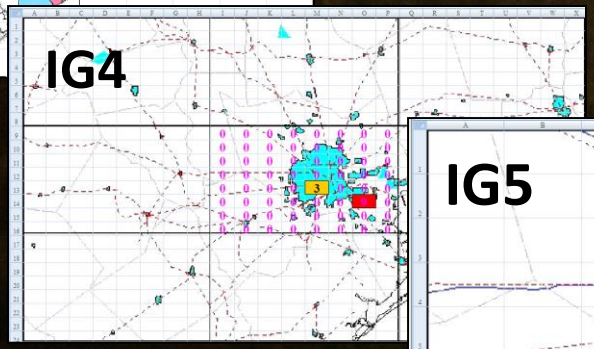
The Infinite Grid℠:

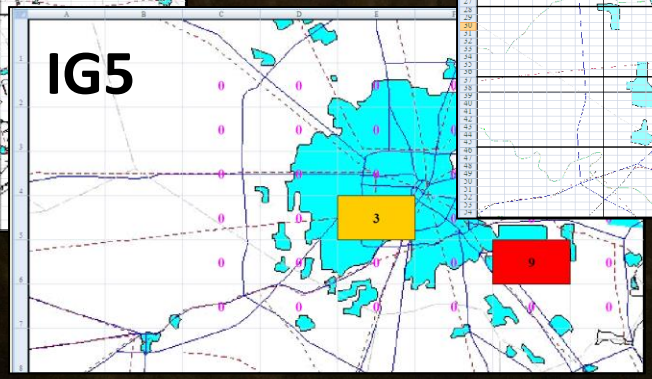
- All IG features and information references are by area, not by vector.
- Areas are Longitude and Latitude tiles.
- Each area has a unique number (XML Tag).
- Relational databases can cross-reference numbers with natural language names, like Harris County, Houston, etc.

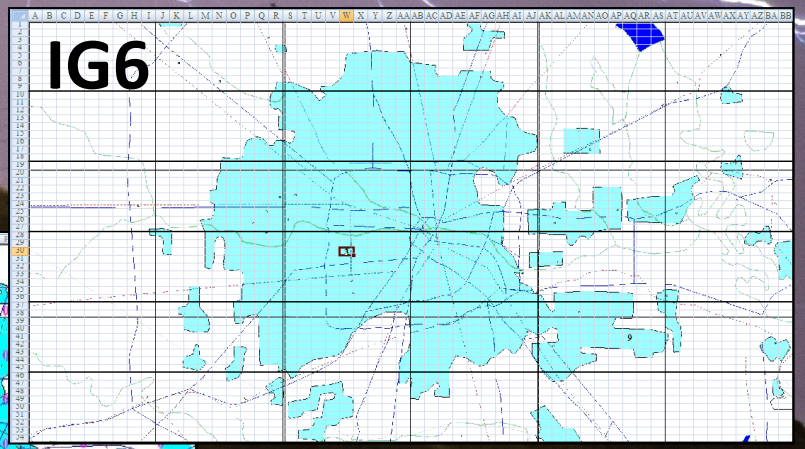












Area based GIS will replace vector based GIS.

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Sources of Infinite Grid^{SM} Data

Public Data

- Topography
- NASA & NOAA
- GEO & GEOSS
- Local Government
- Bureau of Statistics
- Meteorological
- Agricultural
- Geographic
- Health
- Non-profit organizations
- WWW

Commercial Data

- Geotechnical
  - Lightning
  - Temperature
  - Geopressure
  - Satellite
  - Reservoir Characteristics
- Financial
- Trading
- Specialized Databases
- Export
- Sales and Product Data
- Project Data
- Research

The number of legacy maps to index is unlimited.

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Converting & Sponging to the Infinite Grid^{SM}

Databases & Spreadsheets

Data Record + IG Spatial Coordinates & Timestamp

1	3891765.1528	118044.5641	9.0400	1	3891765.1528	118044.5641	9.0400
2	3898512.8571	117813.4571	51.1200	2	3898512.8571	117813.4571	51.1200
3	3871686.6859	117083.4045	52.3200	3	3871686.6859	117083.4045	52.3200
4	3871686.6859	117083.4045	52.3200	4	3871686.6859	117083.4045	5.5000
5	3893227.3520	118272.7626	42.0800	5	3893227.3520	118272.7626	42.0800
6	3898529.1345	118778.2919	51.1200	6	3898529.1345	118778.2919	16.2000
7	3856317.9730	115955.0693	-34.9200	7	3856317.9730	115955.0693	20.3000
8	3882322.6068	117583.2405	-55.5700	8	3882322.6068	117583.2405	6.4000
9	3882602.2188	117600.8708	-55.5700	9	3882602.2188	117600.8708	11.3000
10	3889312.8570	118024.7836	-54.3600	10	3889312.8570	118024.7836	10.6000
11	3893227.3520	118272.7626	42.0800	11	3893227.3520	118272.7626	8.7000
12	3864717.2230	116309.6337	6.7700	12	3864717.2230	116309.6337	10.4000
13	3875902.0520	117010.2930	0.6300	13	3875902.0520	117010.2930	17.6000
14	3882333.2097	117415.0693	-55.5700	14	3882333.2097	117415.0693	10.1000
15	3882612.8232	117432.6997	-55.5700	15	3882612.8232	117432.6997	10.4000
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17	3878708.8006	117017.9400	-57.4900	17	3878708.8006	117017.9400	15.4000
18	3895765.1528	118096.1160	42.0800	18	3895765.1528	118096.1160	11.3000
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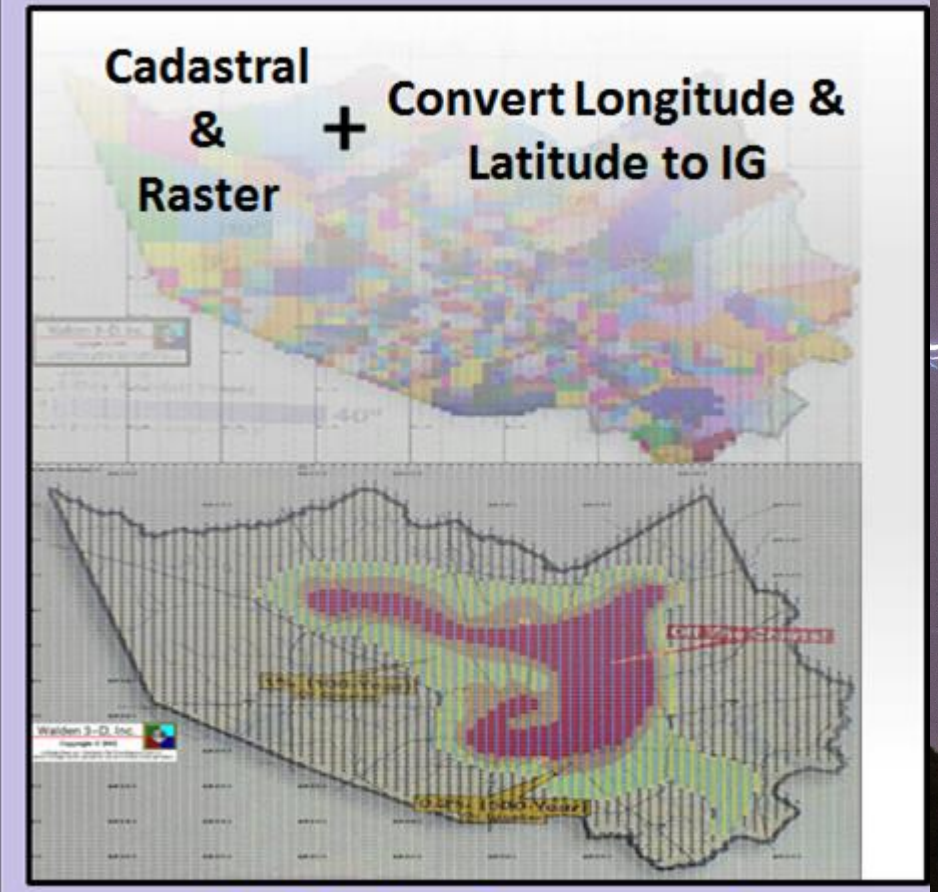
20	3852993.7458	115242.0881	-45.9800	20	3852993.7458	115242.0881	34.6000
21	3863340.0924	115885.9901	6.7700	21	3863340.0924	115885.9901	32.1000
22	3881515.5642	117025.8509	37.7600	22	3881515.5642	117025.8509	8.6000
23	3898292.3041	118087.8506	58.2200	23	3898292.3041	118087.8506	6.6000
24	3854122.7242	115143.3451	8.8000	24	3854122.7242	115143.3451	10.0000
25	3863630.2176	115735.2648	6.7700	25	3863630.2176	115735.2648	7.4500
26	3871459.7762	116225.0013	-17.5100	26	3871459.7762	116225.0013	8.5000
27	3880407.6855	116787.2143	-57.4900	27	3880407.6855	116787.2143	6.3000
28	3896625.3402	117813.0603	60.8900	28	3896625.3402	117813.0603	17.4000
29	3899141.8227	117973.0328	-18.6500	29	3899141.8227	117973.0328	8.1000
30	3862522.1898	115497.2919	54.1900	30	3862522.1898	115497.2919	25.5000

Images & Maps

Cadastral & Raster + Convert Longitude & Latitude to IG



Algorithms automatically index legacy map data.

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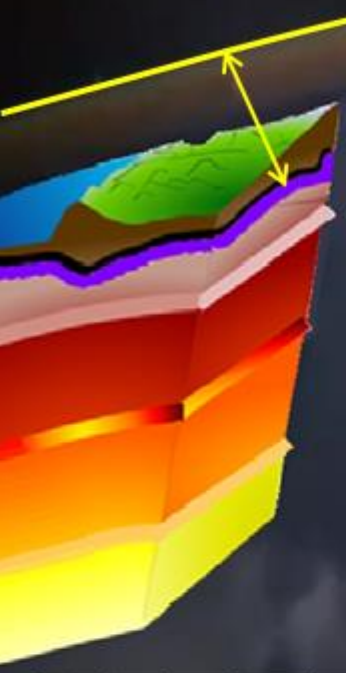
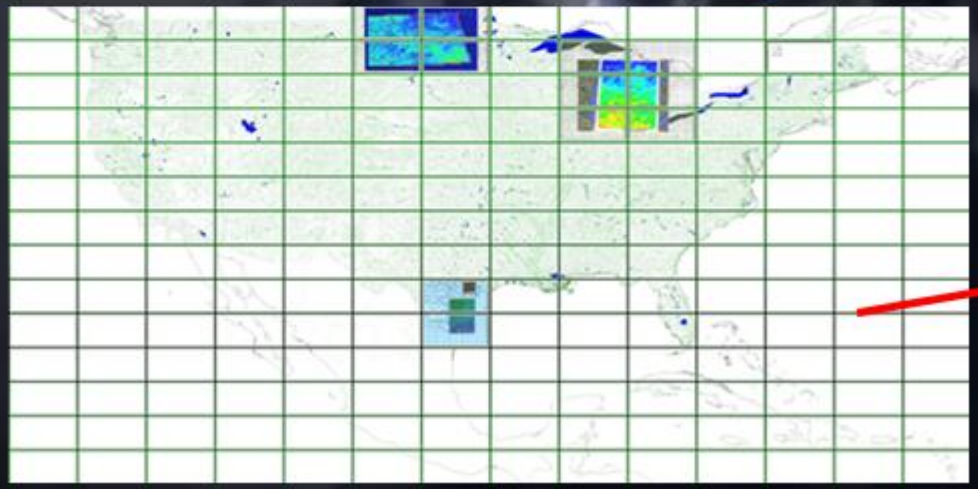
The IG organizes DML's Lightning Data





Lightning data is everywhere, and is a base layer for the IG.

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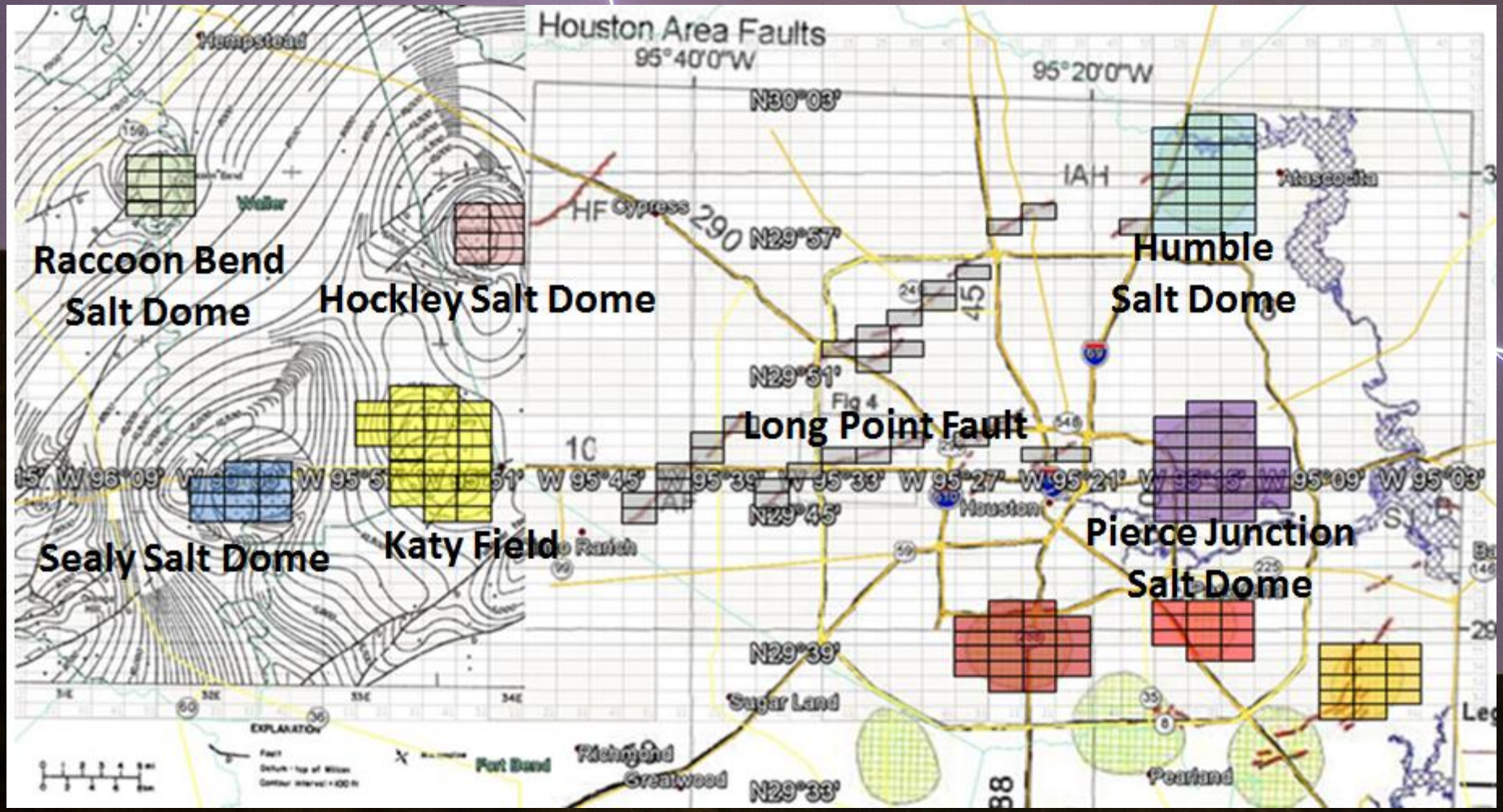
IG DB provides Natural Language Integration



Database linking of XML indexes & names provides a natural language interface.

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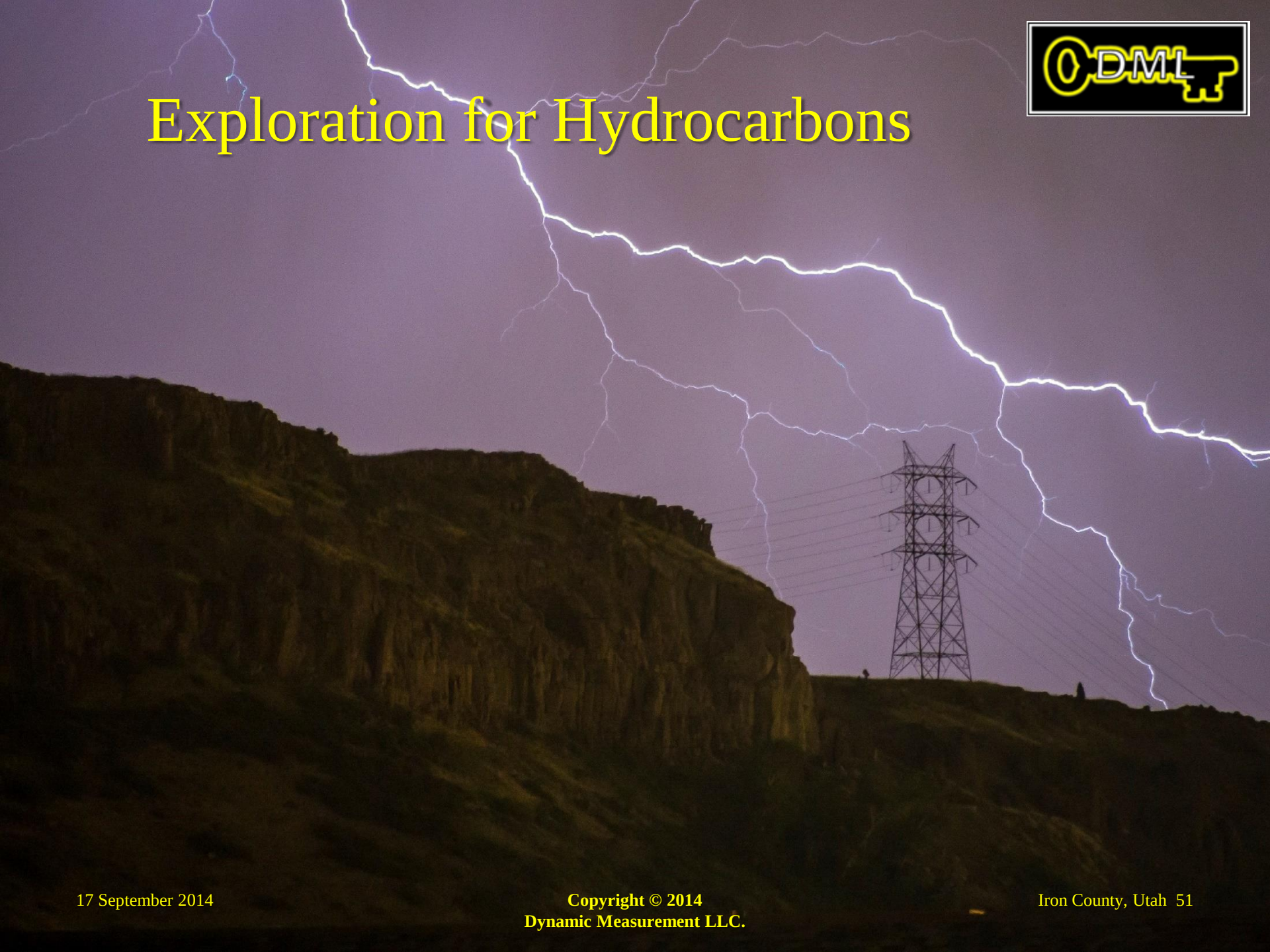
Exploration for Hydrocarbons



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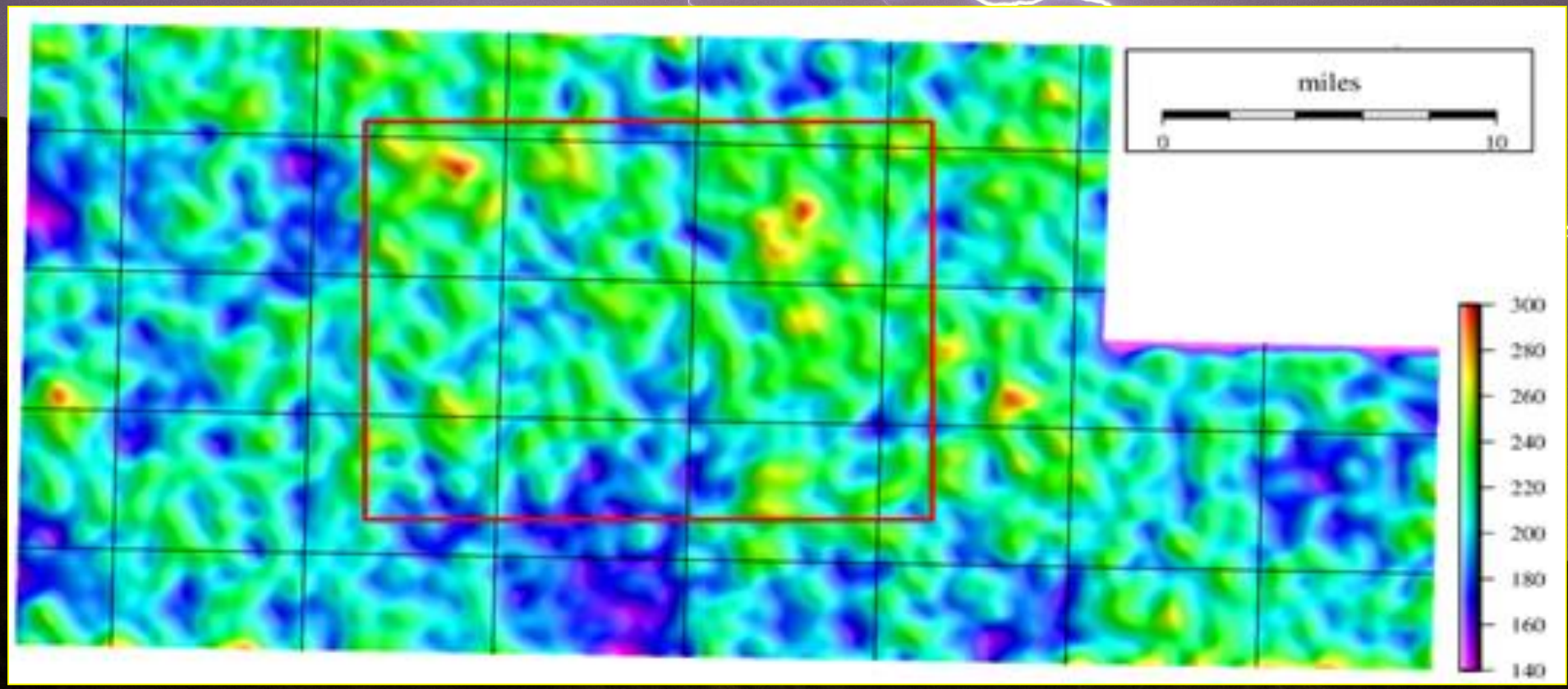
Lightning Analysis Gives A Quicker Regional Overview



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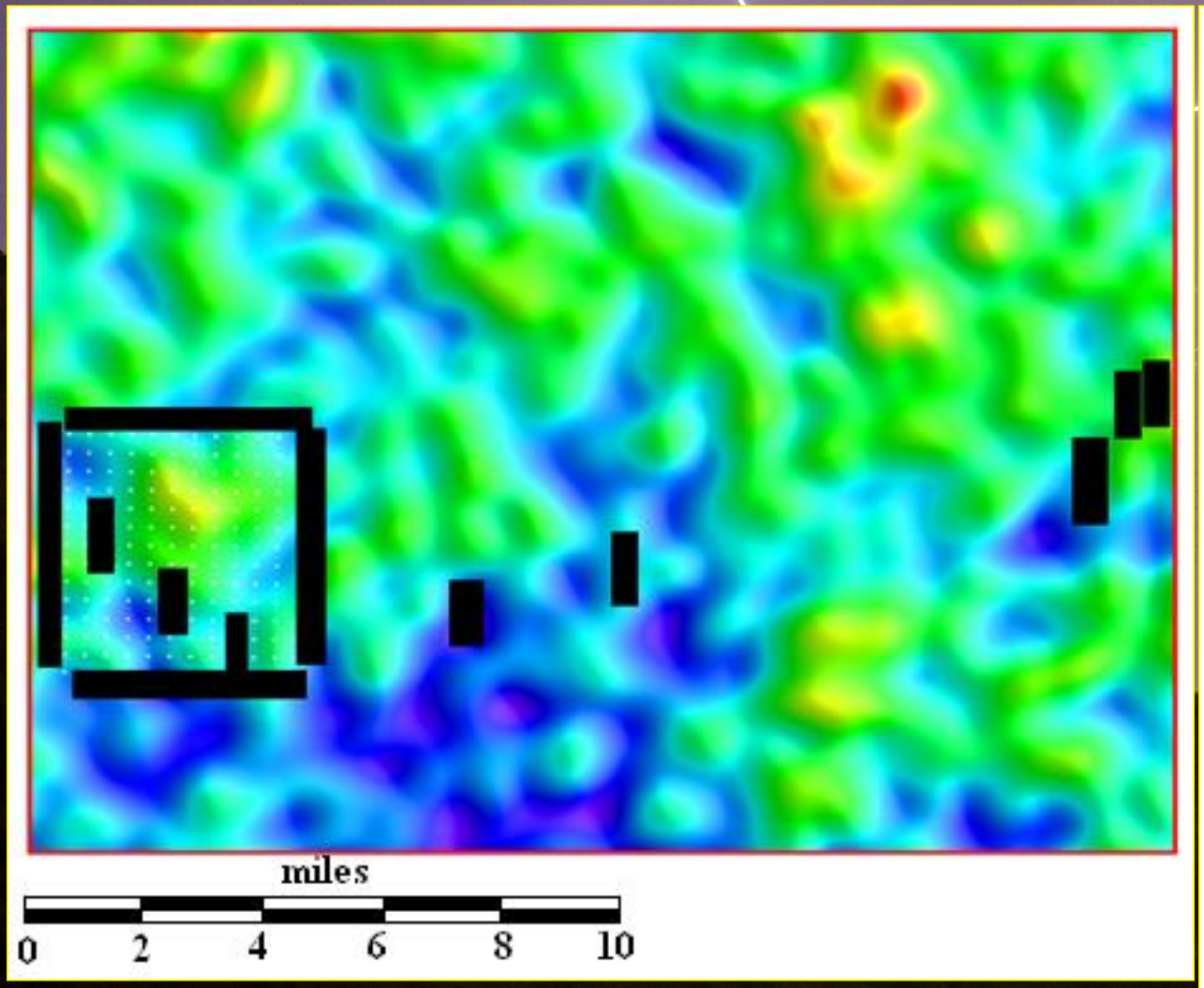
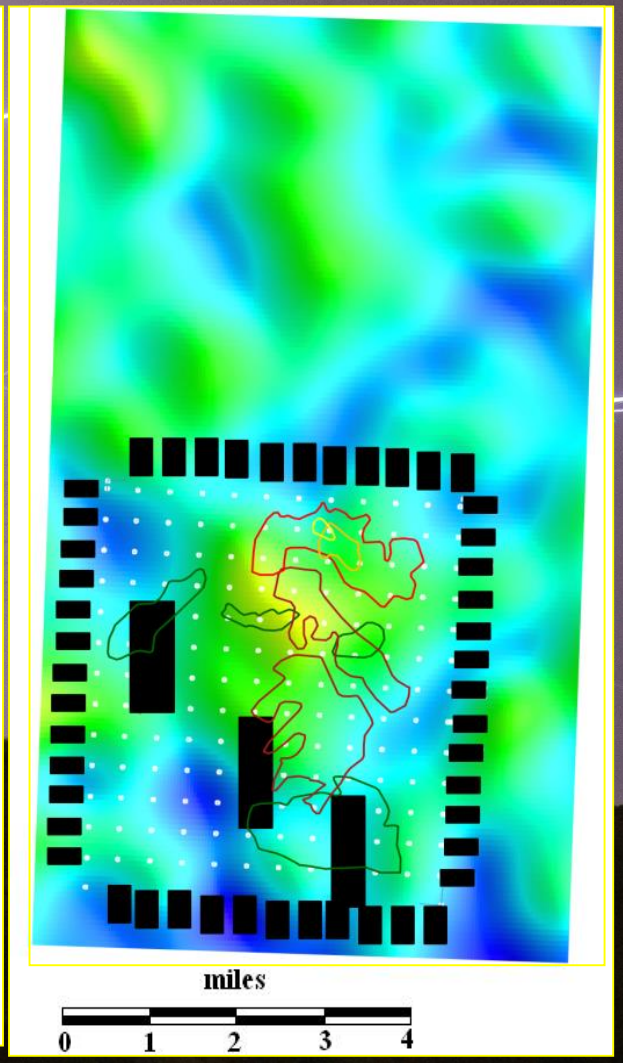
Providing more details at Play Fairway & Prospect Scales





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Exploration for Minerals

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Two Iron Ore Stories

- I recently had an interesting conversation with a client. It turns out that a number of years ago this individual was involved in field work in the northeast, either New York or Connecticut. He was working on a ridge containing a large magnetite vein when a storm blew in and he witnessed repeated lightning strikes all along this ridge. He recalled how the local residents were familiar with this phenomenon and had special lightning protection systems installed on their houses.

  Louis Berent, 26 Aug 2014

- Back when we started DML, one of my second cousins was catching me up on his son, Joe Nelson, and mentioned Joe moved out next to the iron mine in Cedar City because he liked all of the lightning strikes which happen in that part of the valley. This was when I became convinced we were onto something with great potential.

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Planning for Water Conservation

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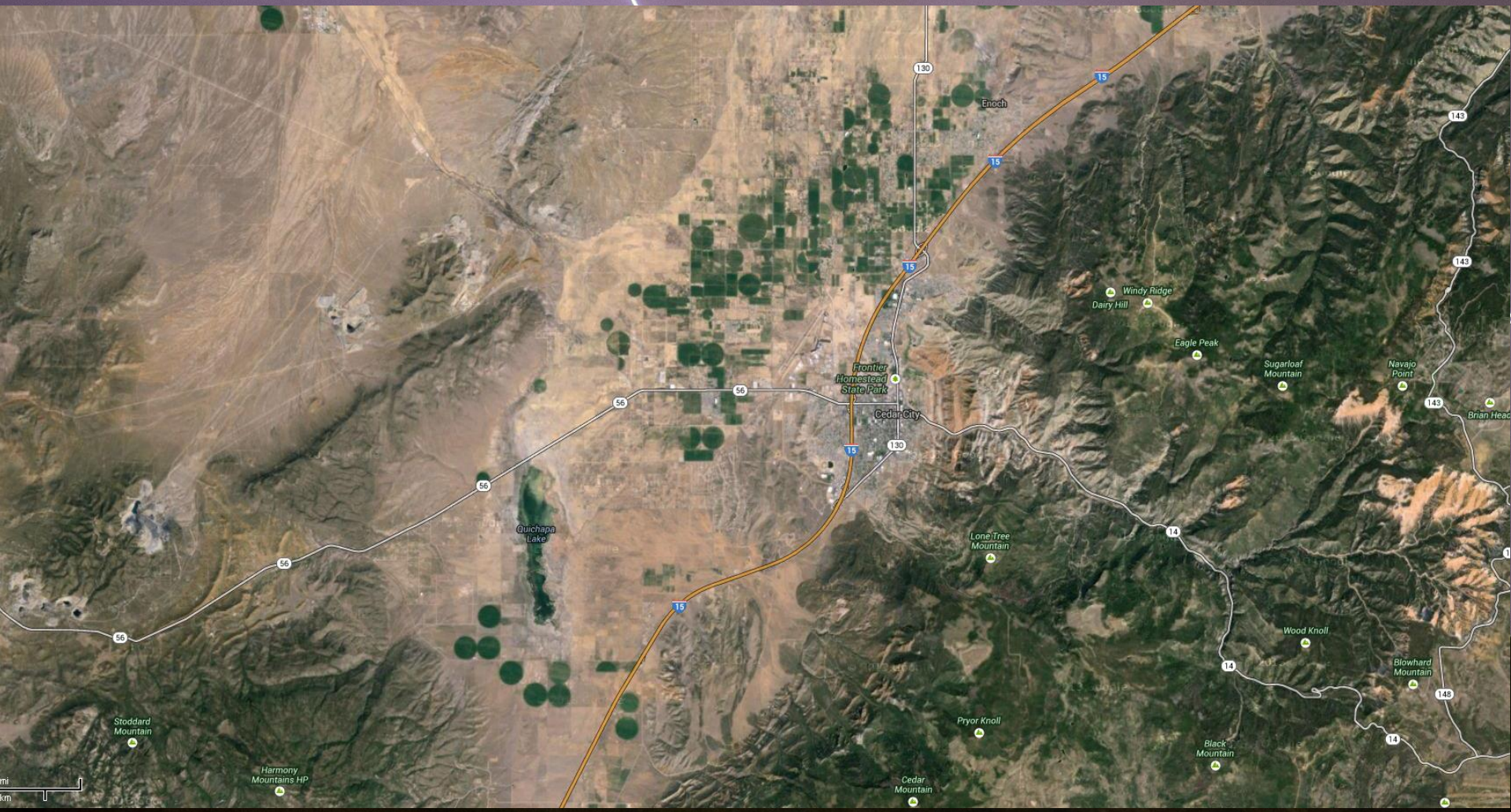
The Cedar City Area



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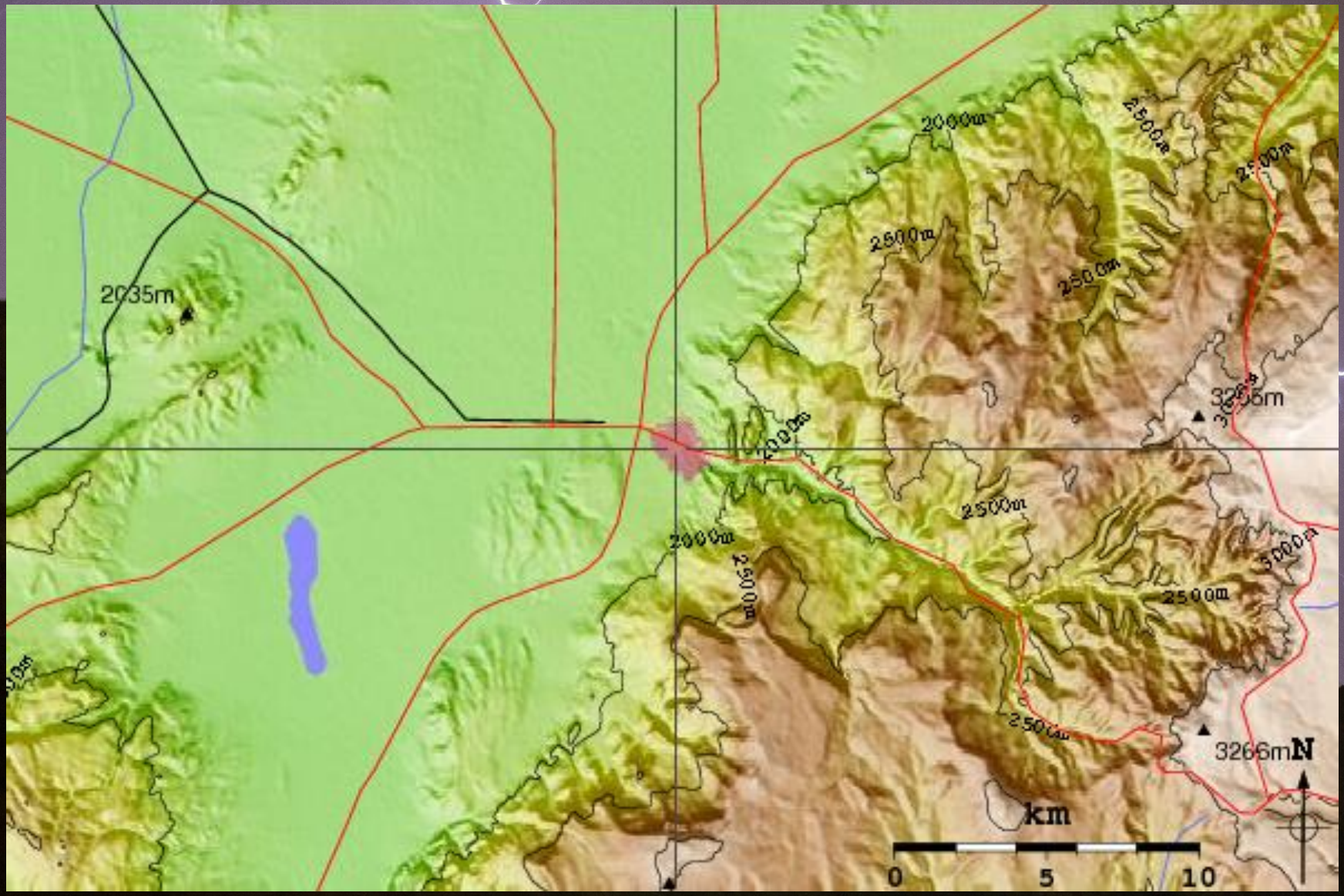
Topography Area Around Cedar



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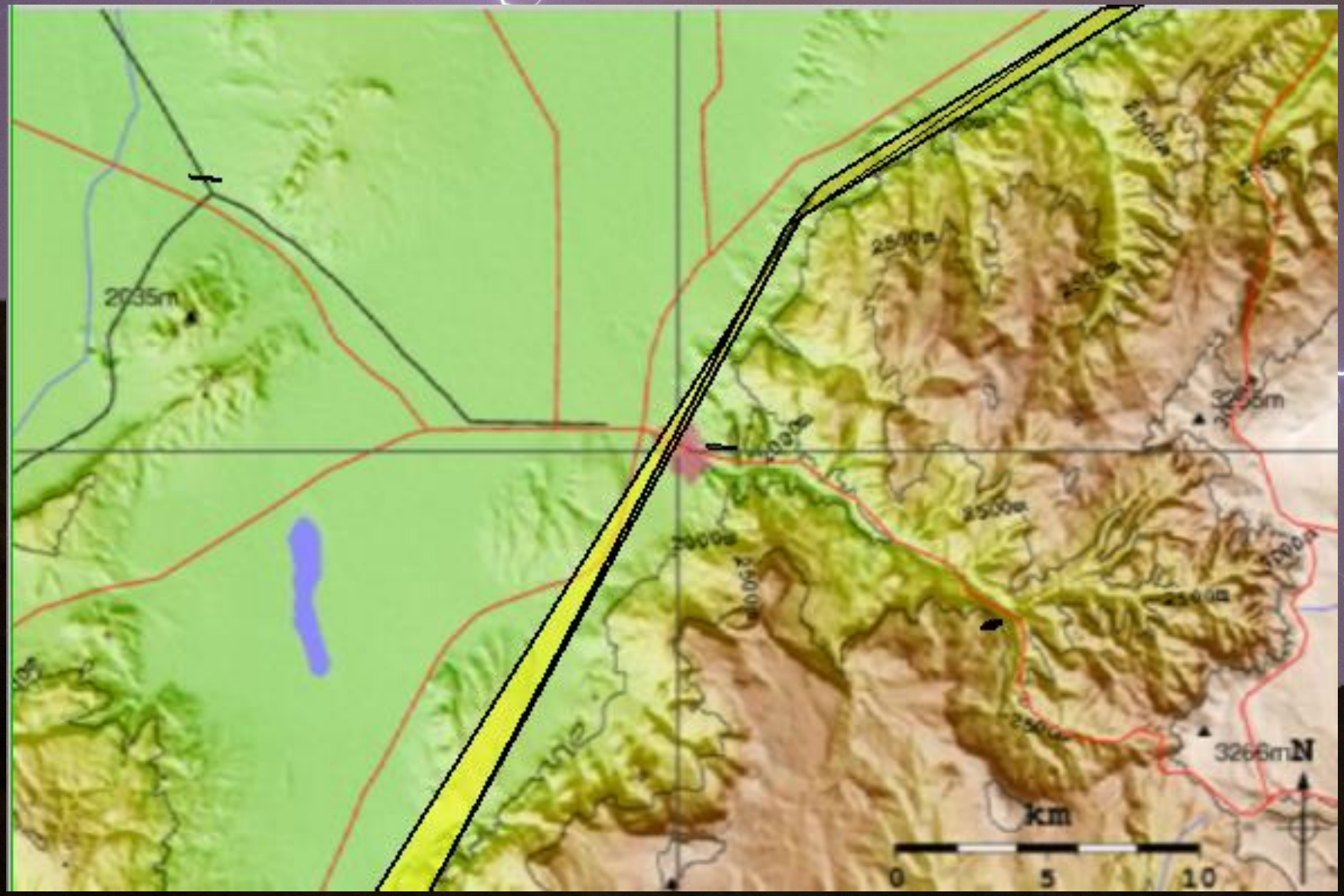
4,000’ Hurricane Fault



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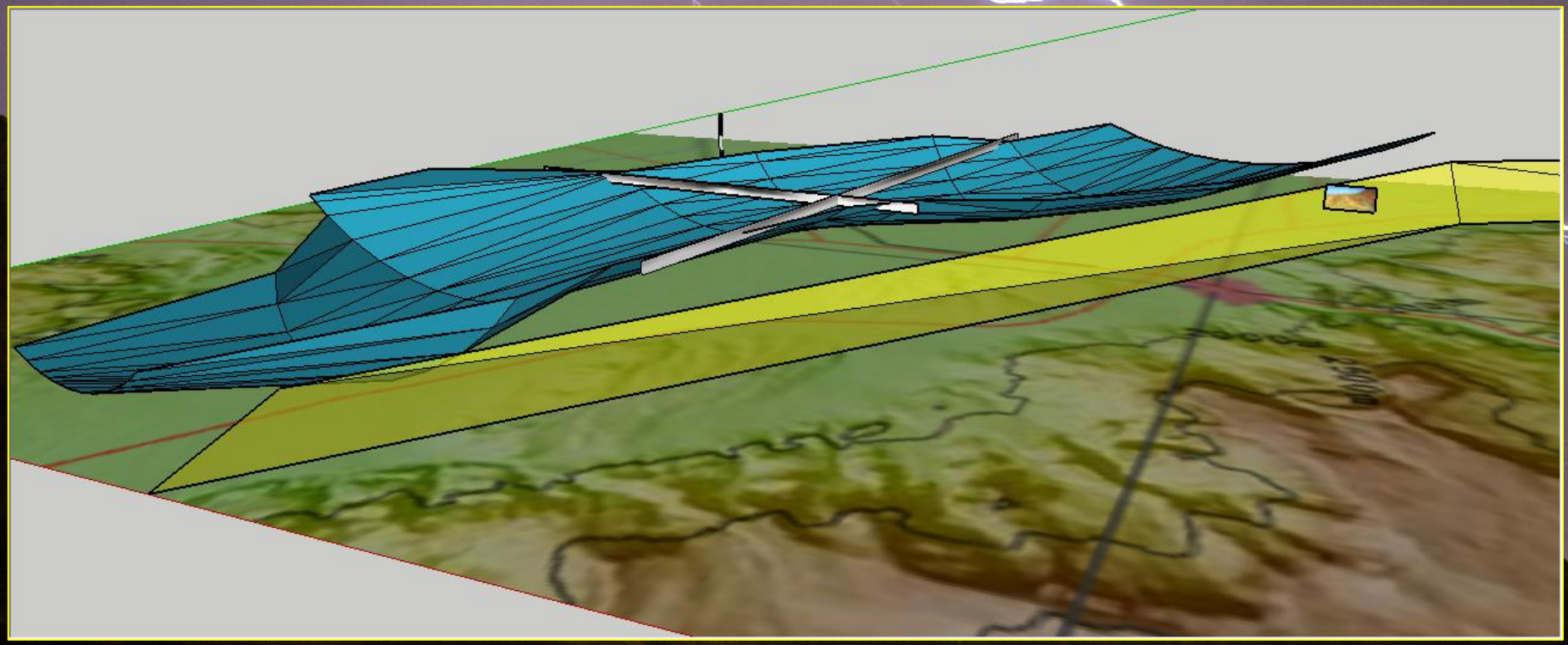
Cedar Valley Aquifer



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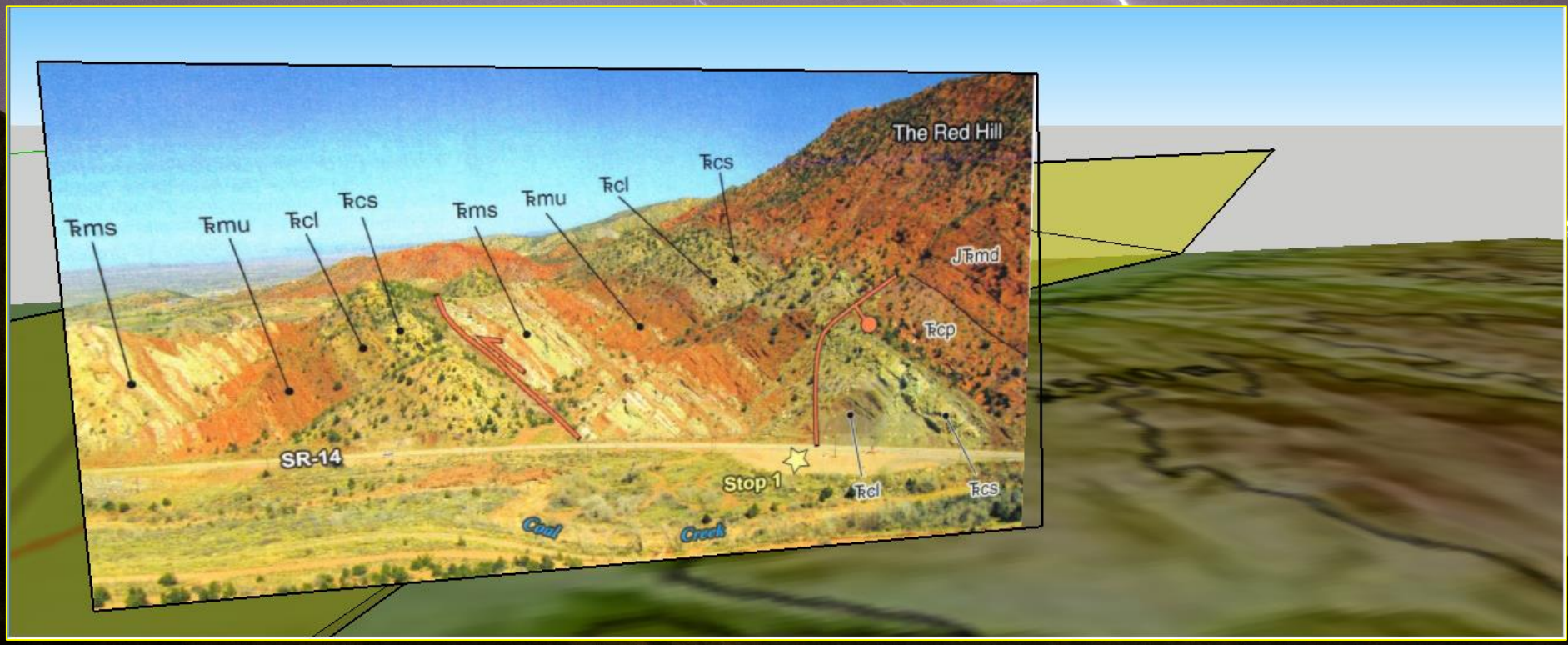
Cedar Canyon Outcrop



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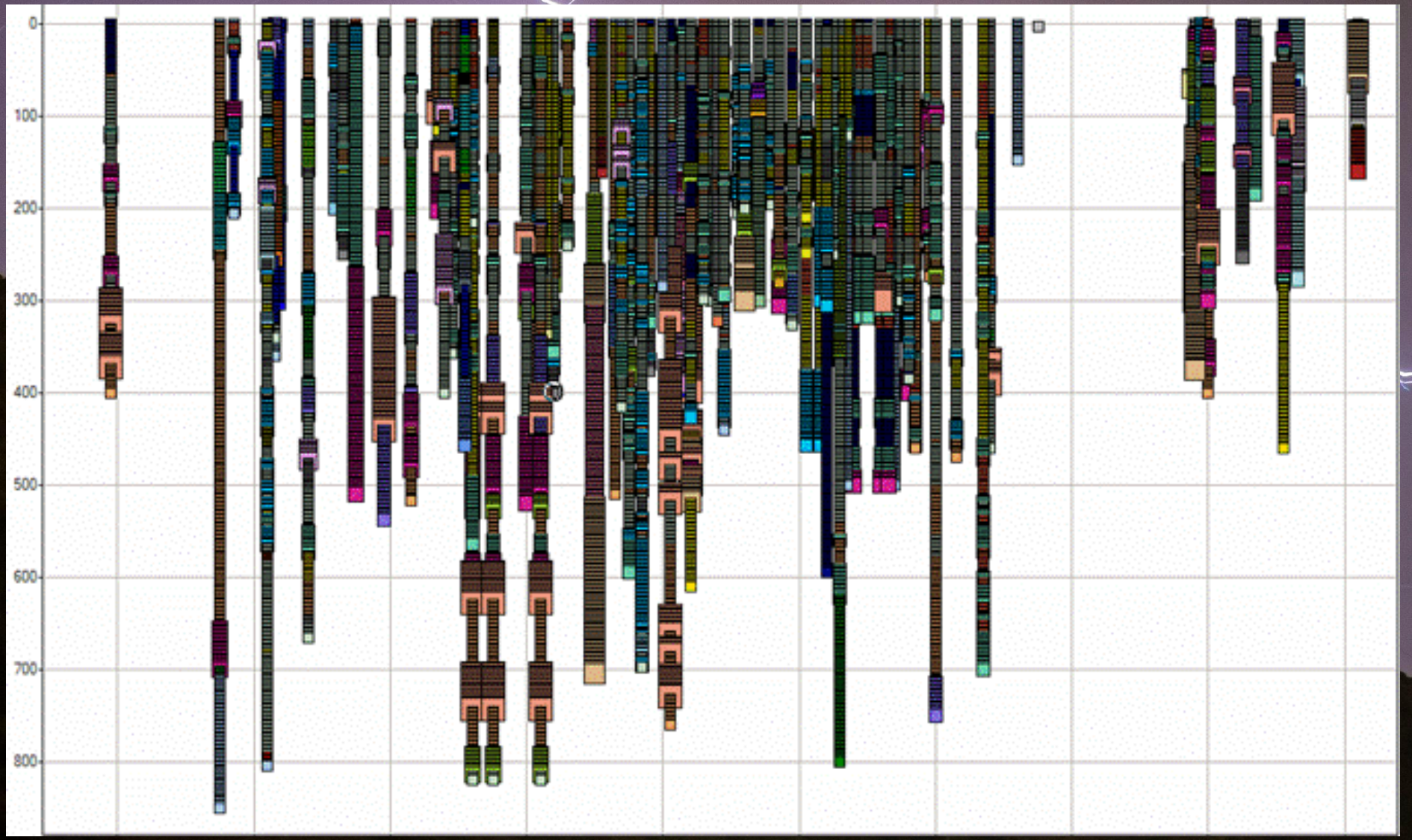
West-to-East Cross-Section



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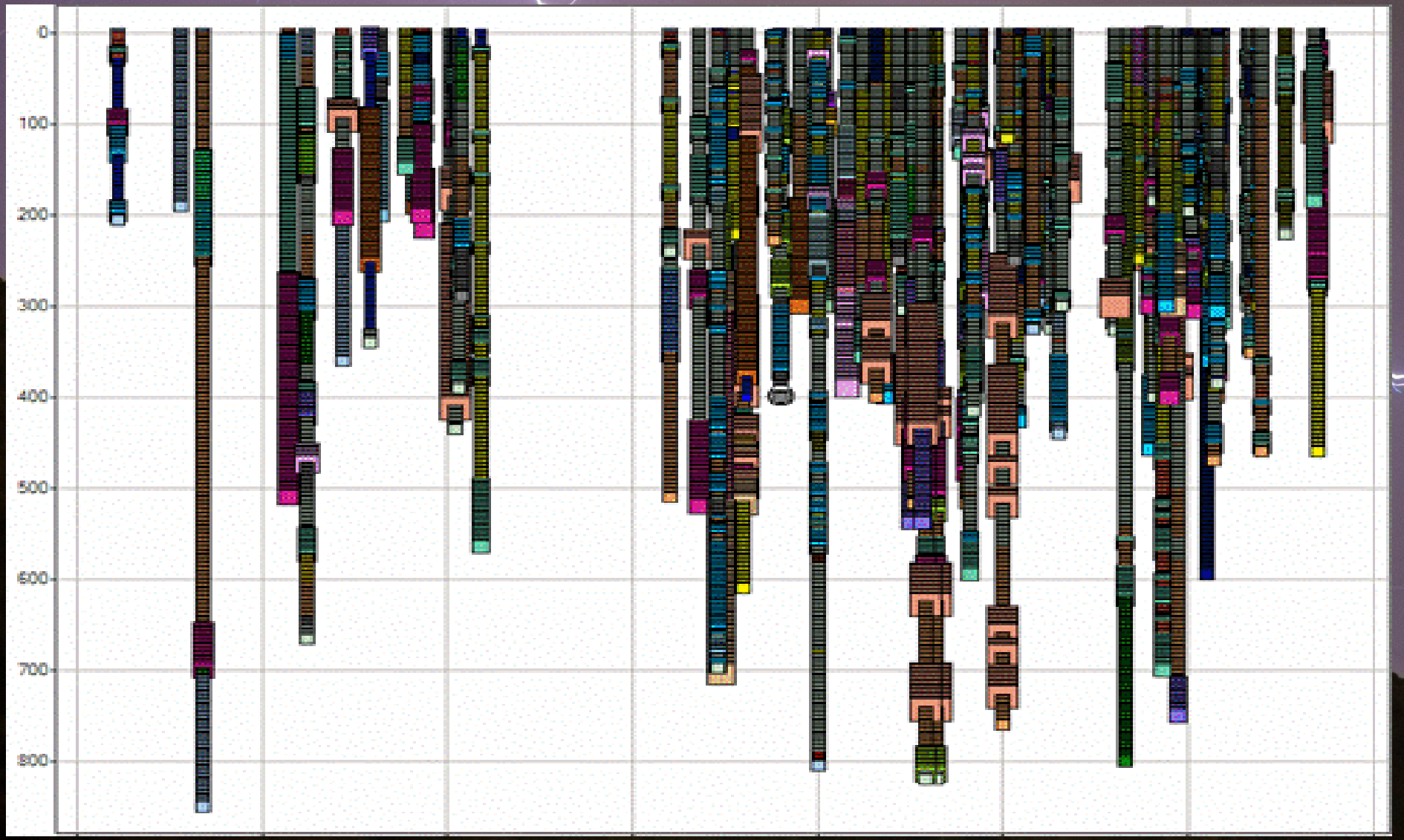
South-to-North Cross-Section



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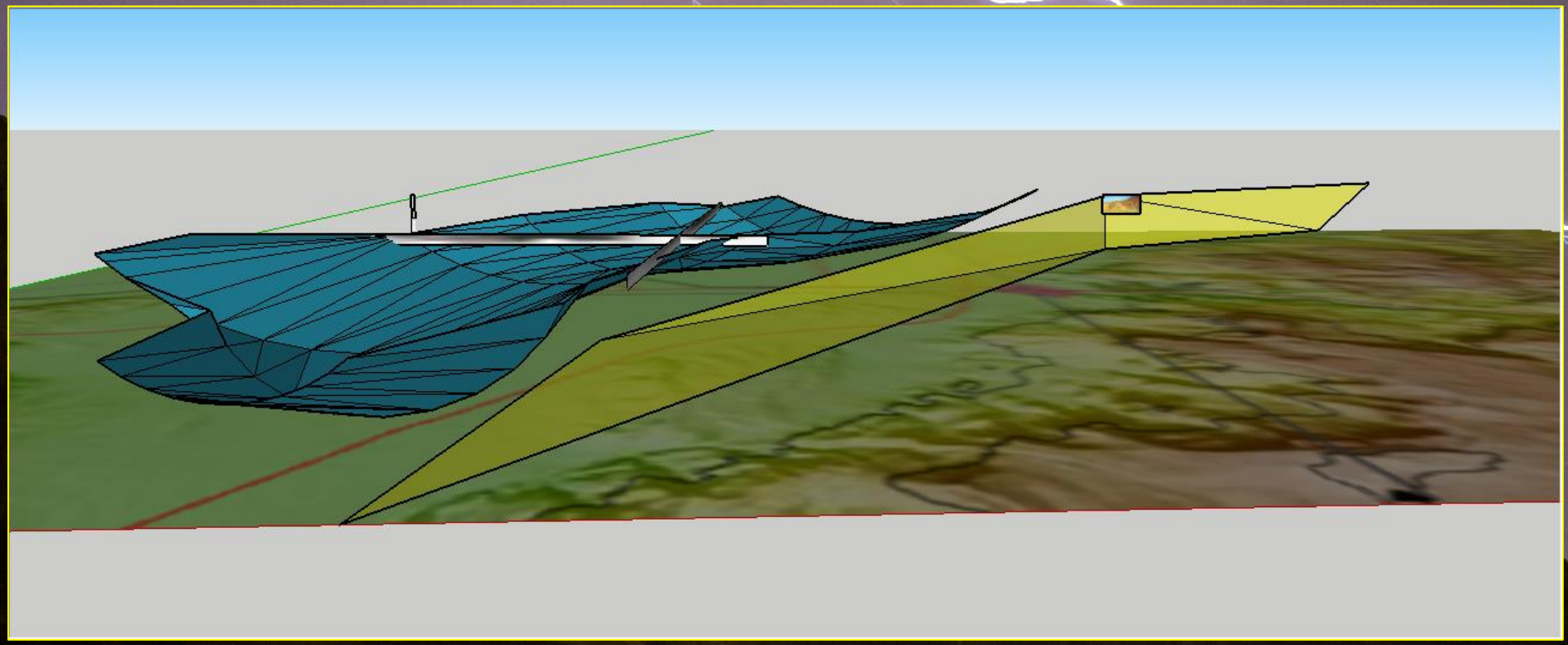
Cedar Valley Aquifer
Water Age: Present to 12,000 years



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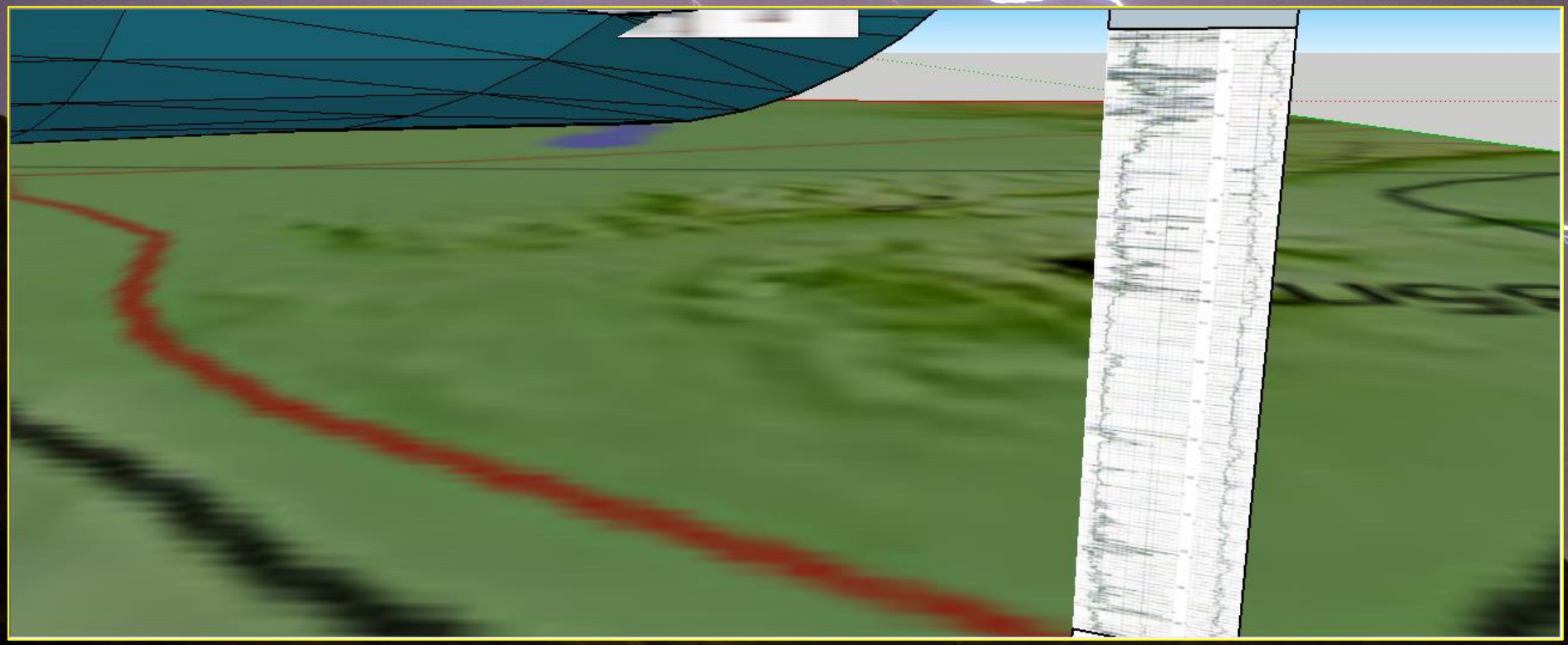
Arco Three-Peaks #1

14,000 foot well with fractured quartz monzonite
from 2,500-2,615 feet & 2,960-3,050 feet



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Woods Ranch

Cretaceous Aquifer Proposed Test Well

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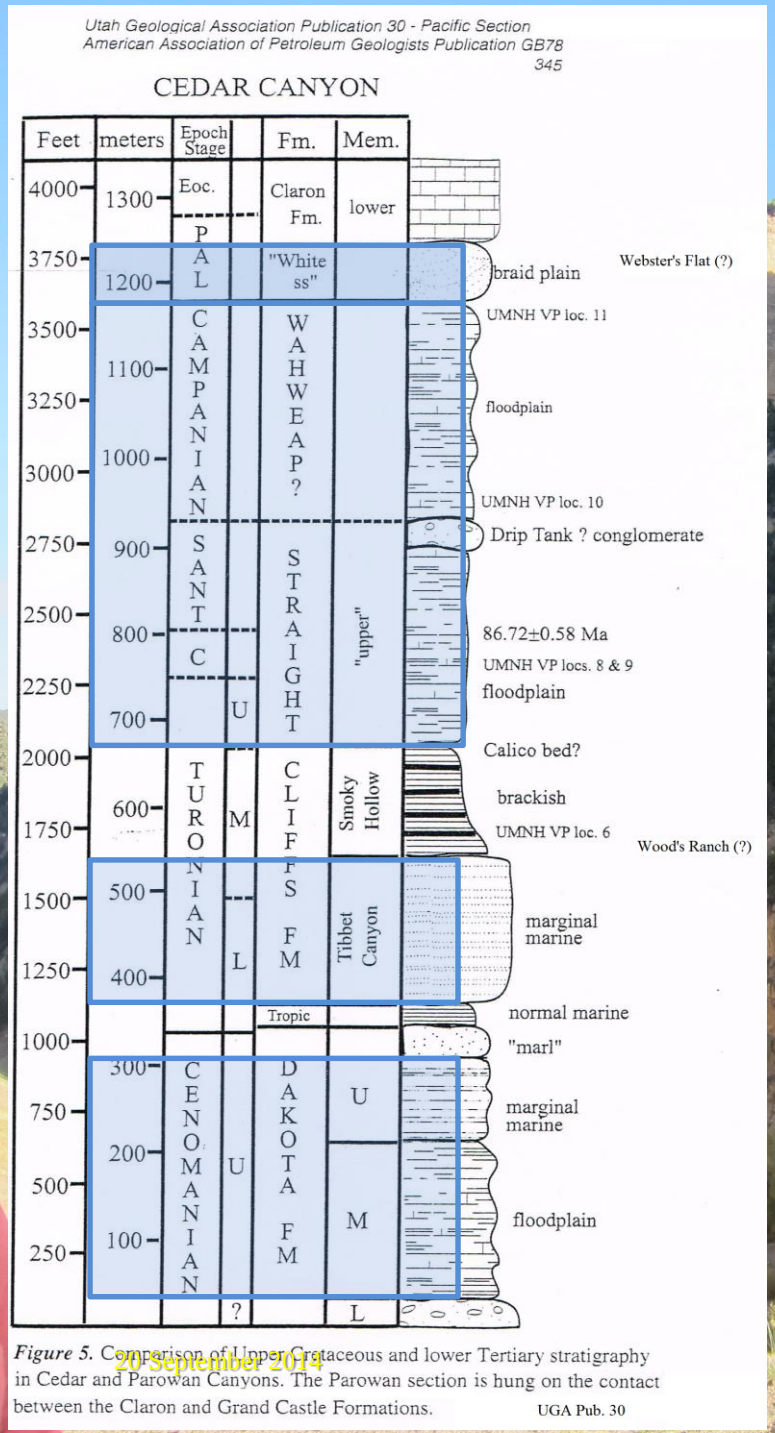

Figure 5. Comparison of Upper Cretaceous and lower Tertiary stratigraphy in Cedar and Parowan Canyons. The Parowan section is hung on the contact between the Claron and Grand Castle Formations. UGA Pub. 30

Type Section

- 32% Porosity in the White Sandstone at Webster's Flat
- 1,700 feet thick
- 20% Porosity in the Lower Cretaceous Sandstones beneath Woods Ranch
- 400 feet thick $15,000 well
- 800 feet thick $50,000 well

2014/09/19 08:37

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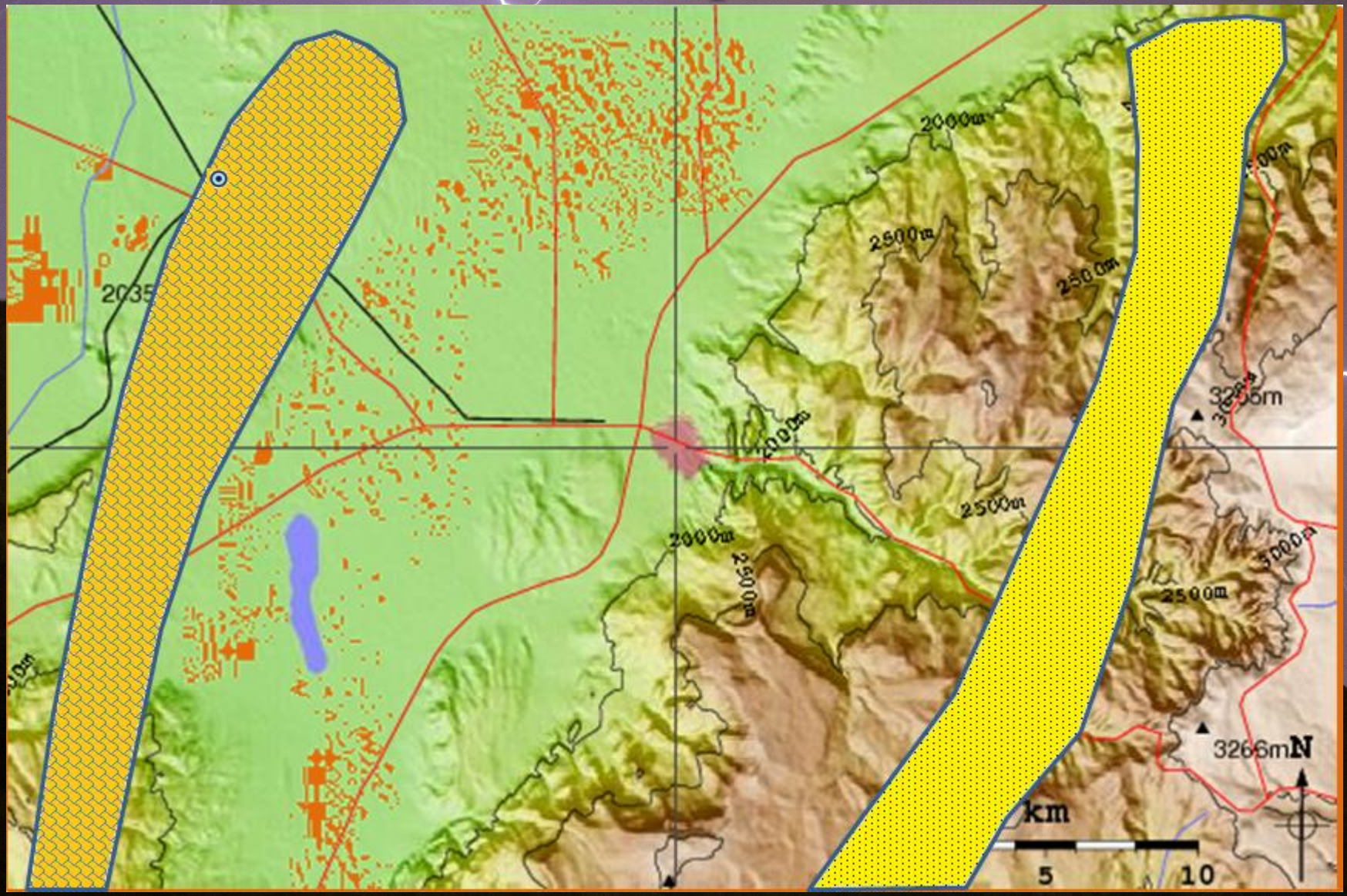
Two Untested Aquifers



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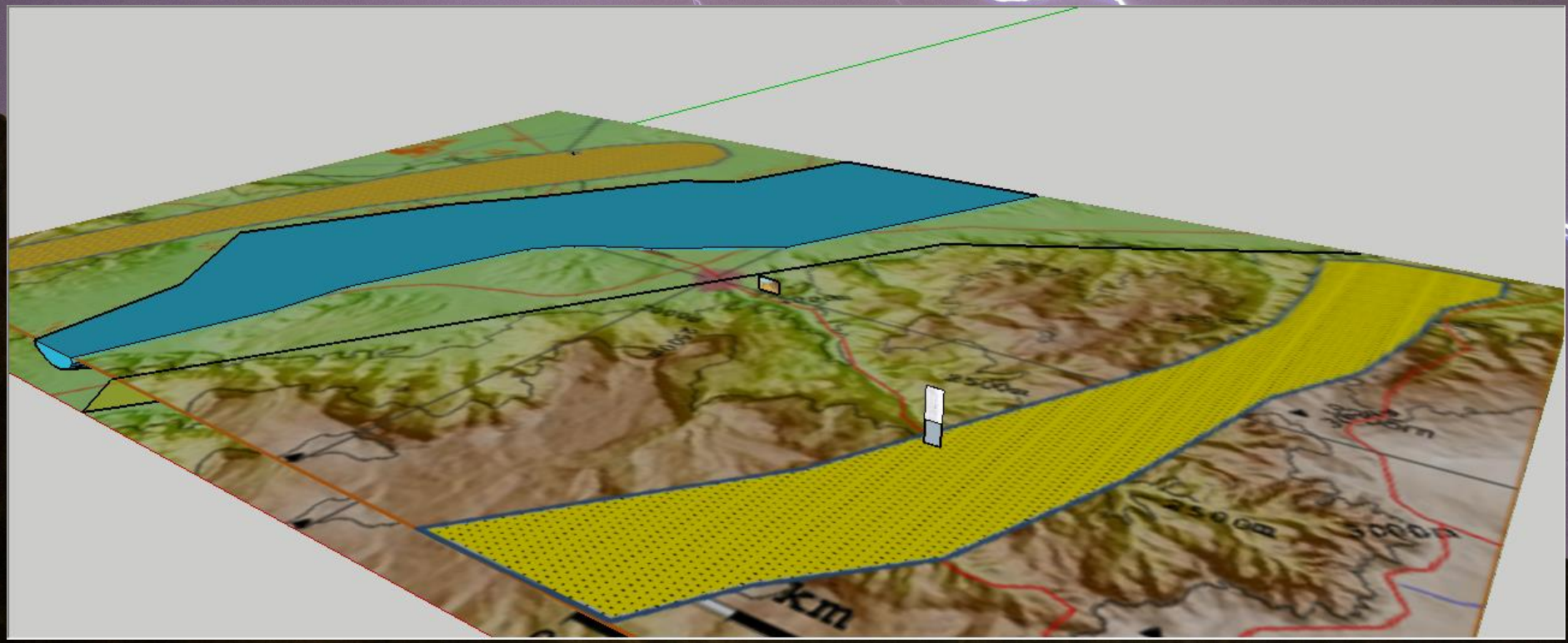
Relationship Between The Three Aquifers



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Advantages of Cretaceous Aquifer

- 20% Porosity in Lower Cretaceous.
- 32% Porosity in Webster's Flat Cretaceous, Stratigraphically equivalent to the Grand Castle Conglomerate in Parowan.
- Expect 2,000 gallons per minute, or at 1,440 minutes/day and 365 days/year, over 100 million gallons/year or 3,228 acre feet/well.
- 15 km x 2.5 km = 37.5 km^2 or 9,266 acres at 20 acre spacing there is room for over 400 wells, or 1.2 million acre feet/year.
- Water dates from present to 1,000 years.
- 2,500 foot head can be used to drive turbines and create electricity.
- Wells could be drilled on top of the cliffs above the slump area and deviated to run into coal creek, so there would be no pumping cost, and with a downhole turbine they generate electricity, draining water back from the slump and helping to stabilize the cliffs.

2014/09/19 08:37

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Drained vs. Non-Drained along the cliffs

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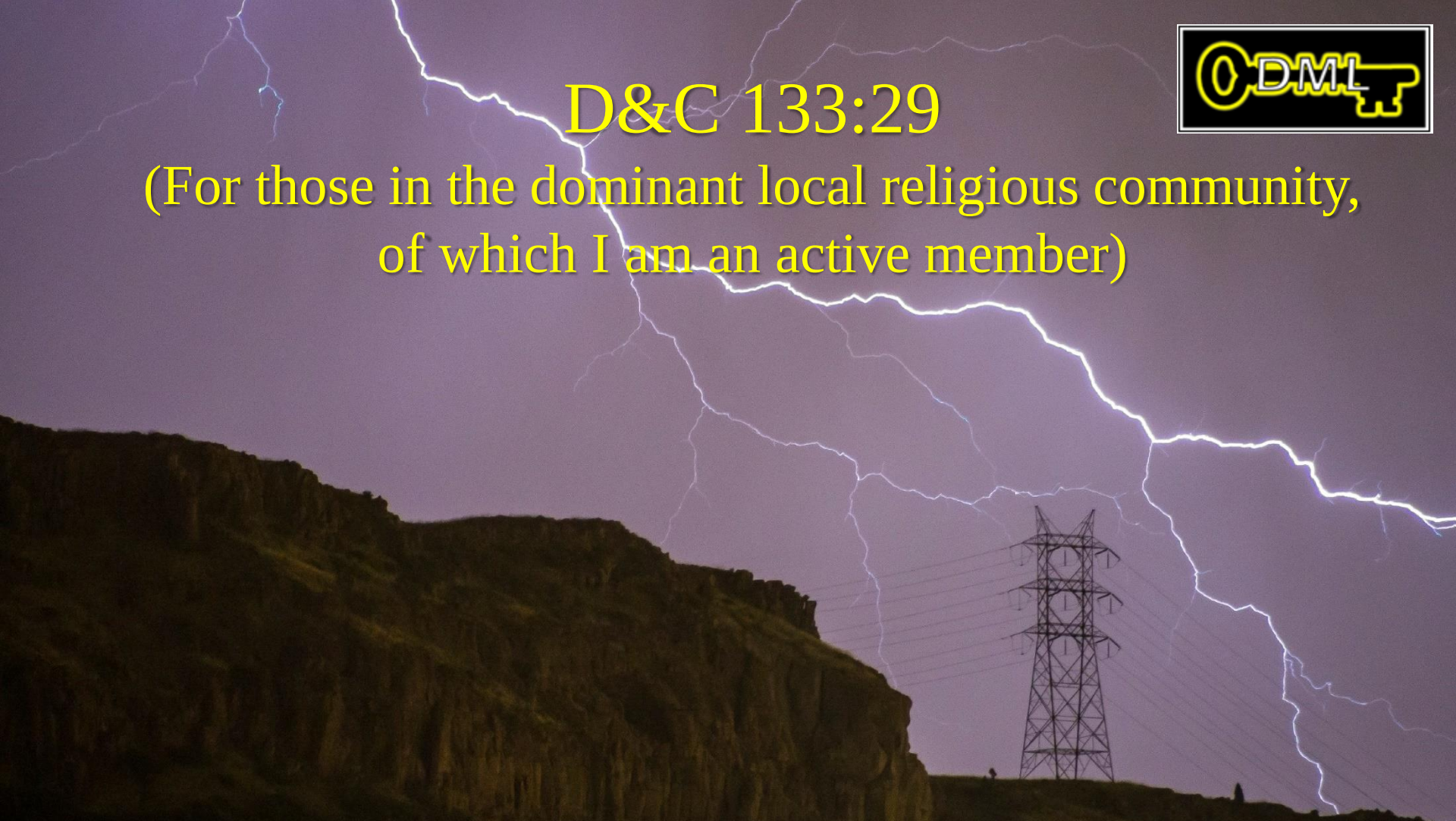
D&C 133:29

(For those in the dominant local religious community, of which I am an active member)



"And in the barren deserts there shall come forth pools of living water; and the parched ground shall no longer be a thirsty land."

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Planning for Development

- Preparation starts with implementing an information based process to manage complexity.
- This information process must be able to:
  - Manipulate data from regional scales to construction's 'nuts & bolts,'
  - Analyze political decisions, and
  - Function as an expert system.
- This starts with understanding the geological foundations of Urban Planning.
- Imagine extending geology to create new Integrated Cities.
- The Urban Machine[SM] uses "N"-Dimensional languages to analyze all types of data, from satellite images to social patterns, and then to integrate the information into designs which optimize interaction between nature and built form.

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Plans

A first step will be to find a way to fund a lightning analysis of Iron County (self or community or research), with long term goals of:

1. Documenting Existing Water and Existing Energy
2. Focusing on New Water Sources and Existing Energy
3. Focusing on New Energy Sources and Existing Water
4. Develop New Water and New Energy Sources

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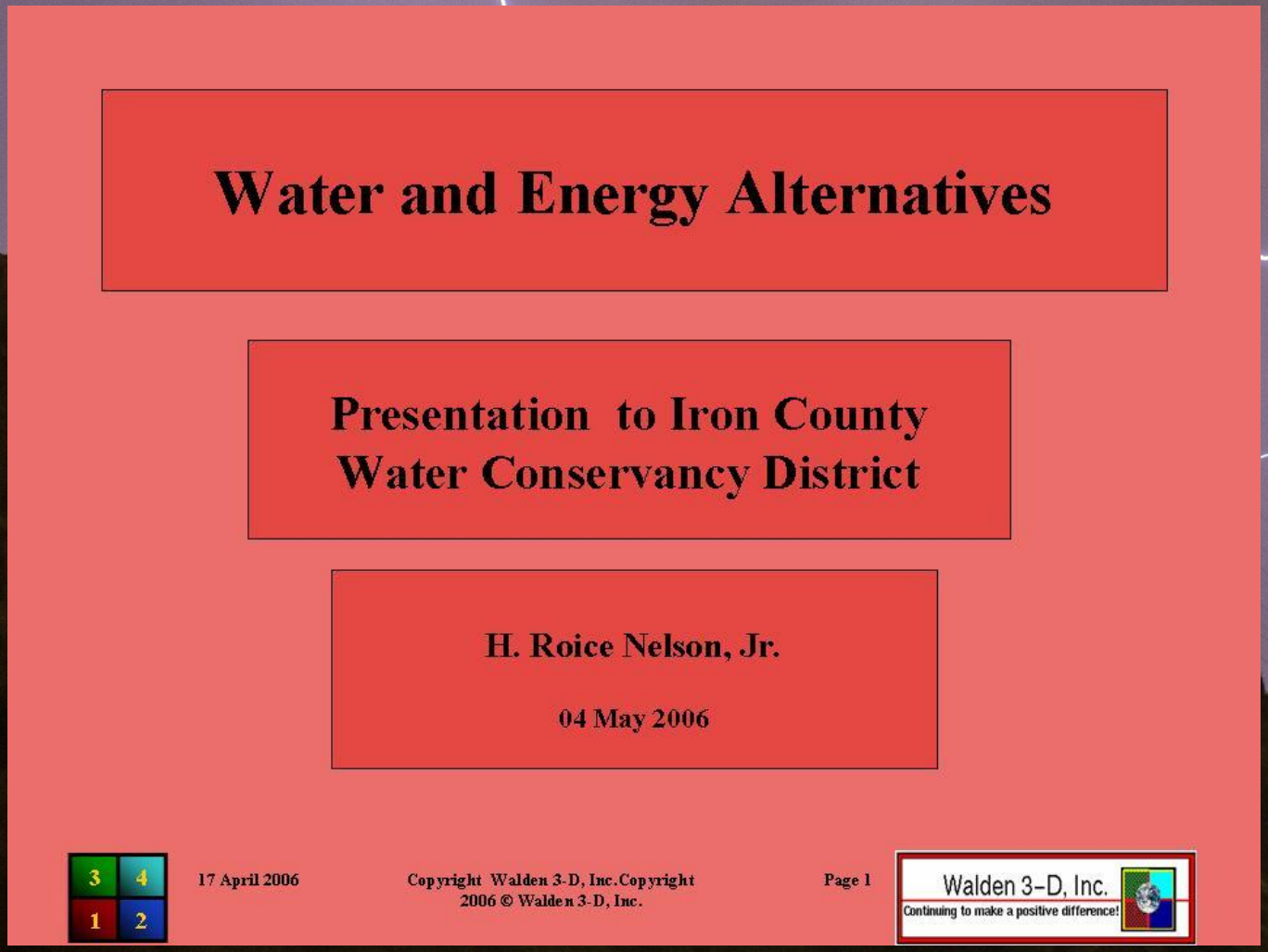
04 May 2006:

http://www.walden3d.com/cedarcity/CedarValleyWater/060417/s01.html



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06 July 2006:

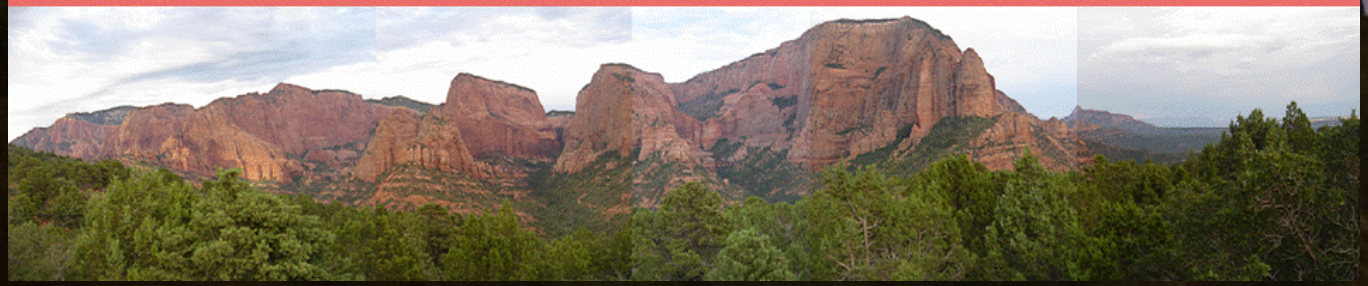
http://www.walden3d.com/cedarcity/CedarValleyWater/060706_50_research_projects/Slide01.html

Water and Energy Alternatives

Presentation for Board Members of the Iron County Water Conservancy District

H. Roice Nelson, Jr.

06 July 2006



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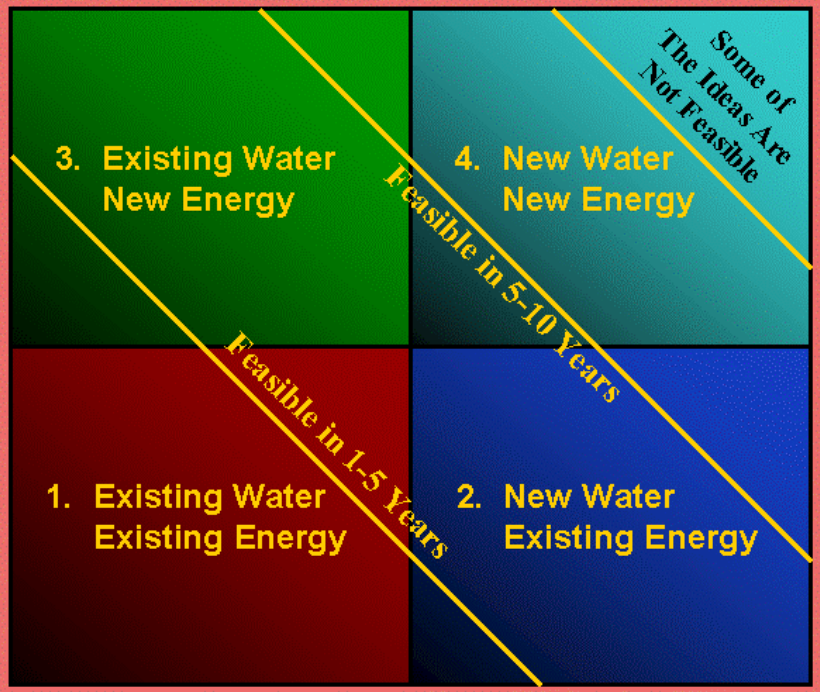
06 July 2006:

http://www.walden3d.com/cedarcity/CedarValleyWater/060706_50_research_projects/Slide05.html

Classification of 50 Proposed Studies:



3 4 1 2

29 June 2006

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Page 5

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Continuing to make a positive difference!

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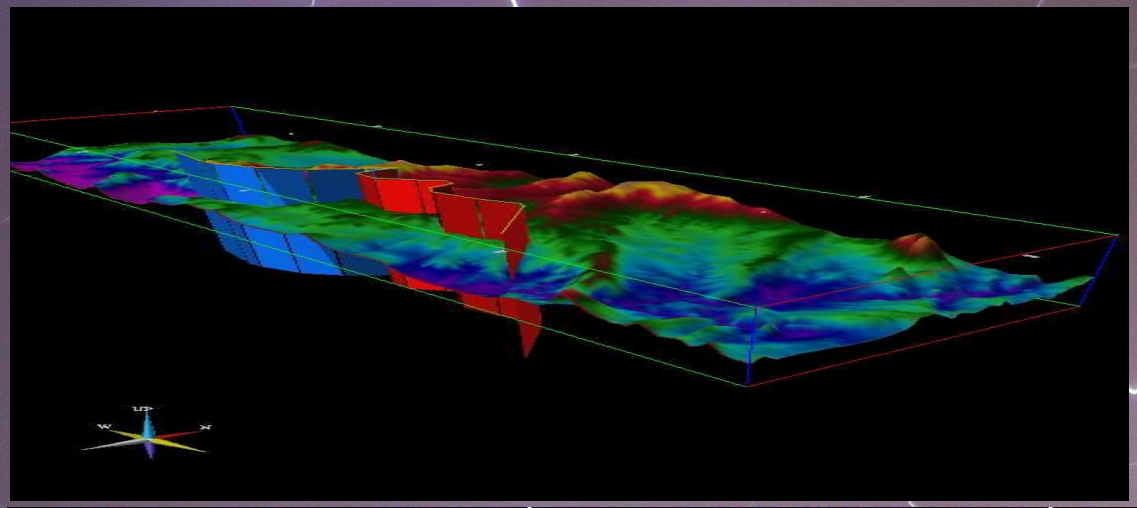
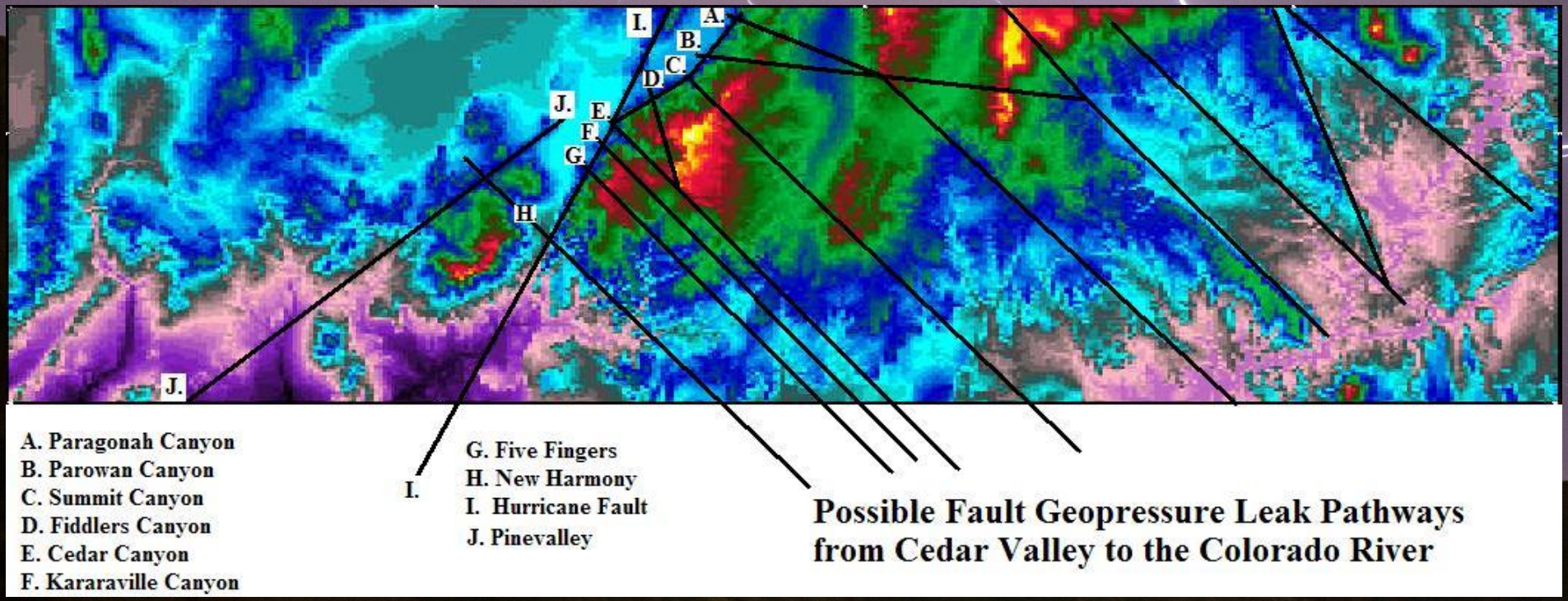


Lake Powell Pipeline displays prepared for Eldon Schmutz



A. Paragonah Canyon
B. Parowan Canyon
C. Summit Canyon
D. Fiddlers Canyon
E. Cedar Canyon
F. Kararaville Canyon

G. Five Fingers
H. New Harmony
I. Hurricane Fault
J. Pinevalley

Possible Fault Geopressure Leak Pathways from Cedar Valley to the Colorado River

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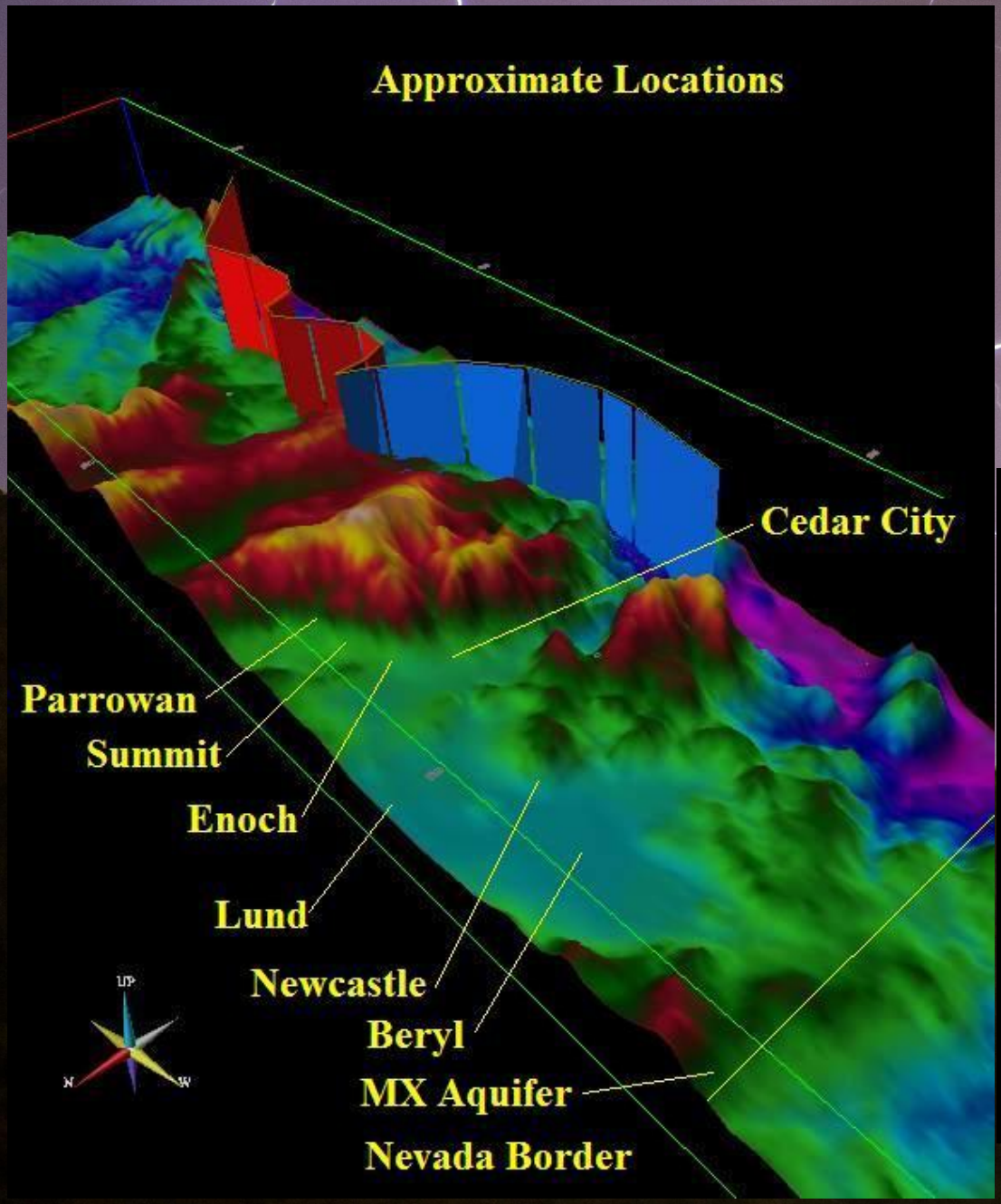
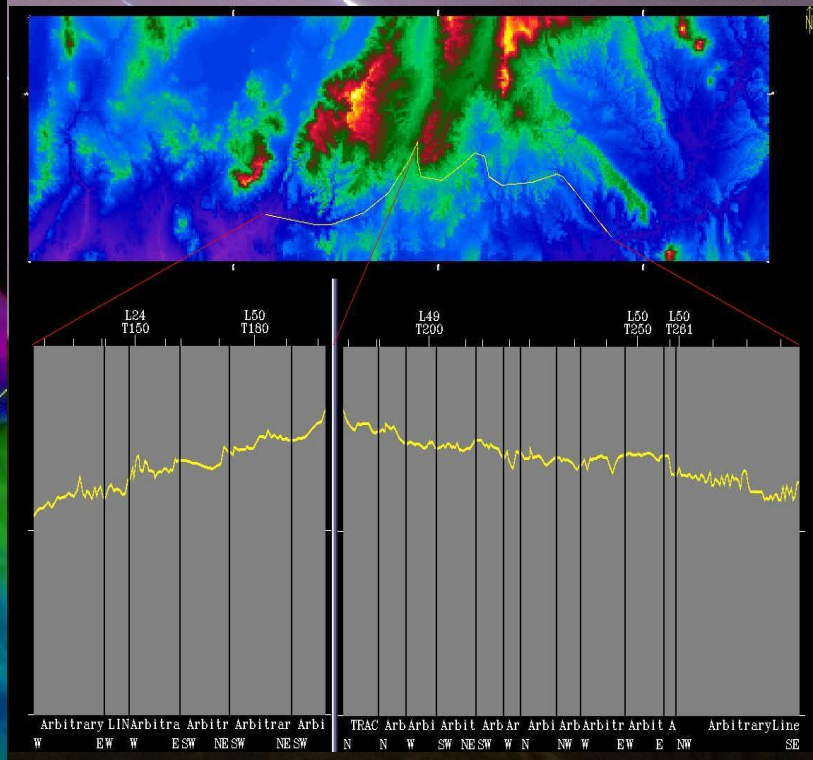
MX Aquifer displays prepared for Eldon Schmutz





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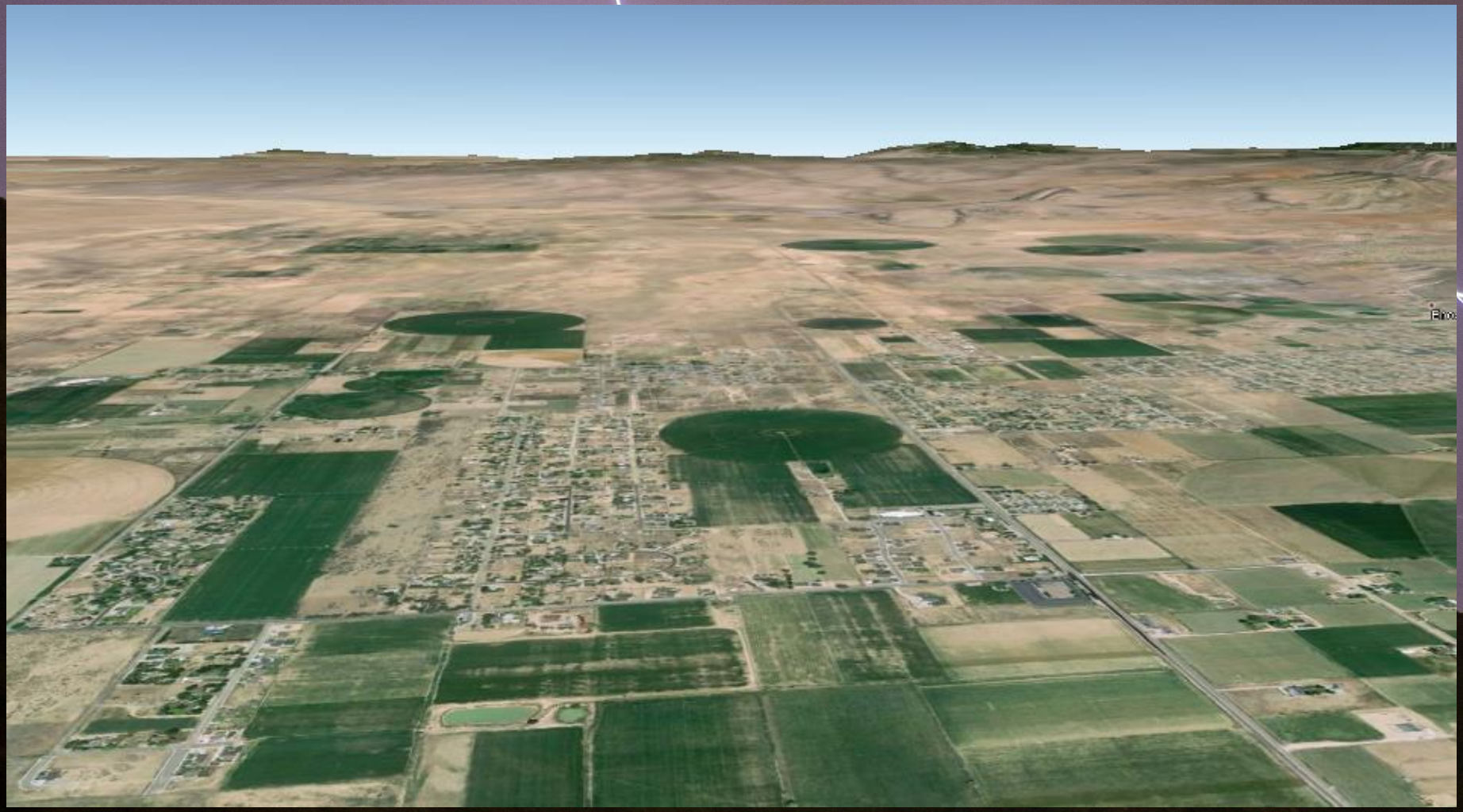
2014



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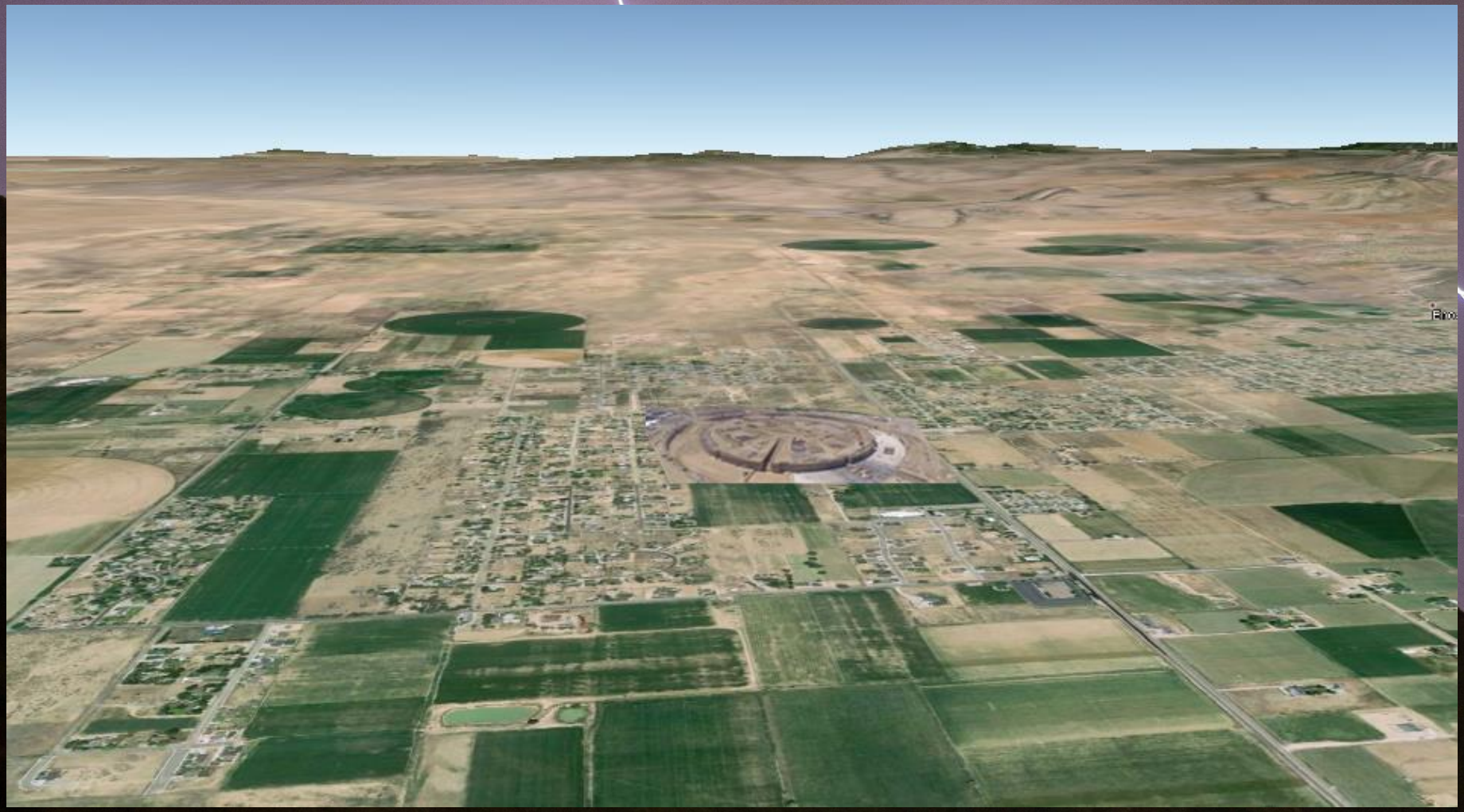
2024



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2024

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2034

This undated rendering provided by Apple Inc., shows a proposed 150-acre campus built around a gigantic circular building made almost entirely of curved glass, with a heavily landscaped center. Apple?s plans for a massive new campus in Silicon Valley that former CEO likened to a spaceship are moving forward. The planning commission in Cupertino approved the project on Wednesday, Oct. 2, 2013. (AP/Apple Inc.)

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Summary

- Lightning Data Analysis is a New Geophysical Data Type
- Resistivity Volumes from Lightning Databases are Frameworks
- Geologic Frameworks are critical for stable growth of society
- Exploration for Hydrocarbons is unlikely in Iron County
- Exploration for Minerals can be tested in Iron County
- Planning for Water Conservation is critical for Iron County
- Development in Iron County is limited by Water and Energy
- Lightning Analysis is one of a series of tools DML and W3D intend to test the viability and usefulness of here in Iron County

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