Deriving Exploration Maps and Rock Property Volumes from Lightning Databases

H. Roice Nelson, Jr. & Dr. D. James Siebert

22 January 2015
Outline

1. NSEM - A new geophysical data type
2. The meteorology behind lightning databases
3. Calculating rock property volumes from lightning databases
4. Examples of using lightning databases to map geology
1. NSEM – (Natural Source ElectroMagnetics) – a new geophysical data type
Lightning Data Analysis demonstrates strikes are tied to geology

Density map shows Lightning Strikes Cluster

Attribute map shows Salt Domes in Same Area
Attribute Maps related to major copper mine being developed in Arizona
Technical Merit & Economic Benefits

- Maps, Sections, and Volumes
- Evergreen Data
- 17 year database US & Canada
- 4 year database worldwide
- Integrates with other data
- Simple Solution
- Patented, & Patent Pending

- 2 month project turnaround
- Larger Area – Less Expense compared to 3-D seismic
Each new data type has sparked a step change in new revenues and cost avoidance for upstream oil and gas companies.
2. The meteorology behind lightning databases
Lightning density regionally controlled by meteorology, and locally controlled by terralevis (shallow earth) currents.
Earth: A Self-Repairing Capacitor

Lightning Strikes normalize the capacitor
350 million annual Lightning Strikes - a rich database to mine

Lightning Strikes can travel 250 km (155 miles) cloud-to-cloud, or 2 ½ times the distance of Sprites or Elves.

Lightning Strike locations primarily controlled by terralevis (shallow earth) currents.
Lightning recorded for early storm warning, safety, **insurance**, and meteorological purposes.
330 Sensors record U.S. lightning strike locations with 650-980 feet (200-300 meter) horizontal resolution.
Lightning Strike Measurements

- Location
- Time and Duration
- Rise Time
- Peak Current
- Polarity
- Peak-to-Zero
- Density
Upward Lightning tied to geology
Main lightning bolt tied to geology
Proven and Patented Technology

United States Patent

Patent No.: US 8,344,721 B2
Date of Patent: Jan. 1, 2013

Method for Locating Sub-Surface Natural Resources

Inventors: H. Roico Nelson, Jr., Houston, TX (US); Joseph H. Roberts, Houston, TX (US); D. James Siebert, Katy, TX (US); Wulf M. 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)

References Cited

U.S. Patent Documents

See application file for complete search history.
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
Email: Mary_Broussard@fmi.com
3. Calculating rock property volumes from lightning databases
Topography and Lightning Density Arizona
LIDAR Extended with NSEM Analysis

35 ft cap

See Lightning …

DML

… think DML & solutions

West Cote Blanche Bay

Weeks Island

Cote Blanche Island

668

83

8.8 mi

5.8 mi

2.3 mi

6.0 mi

7.3 mi

9.0 mi

10.6 mi

0.0

-5.0

-10.0

-15.0

-20.0

-25.0

-30.0

-35.0

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15-Jan-22

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Lateral Strike Resolution 200-300 meters
The Atmospheric Capacitor

Plate 1

- 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

Plate 2

Dielectric
Relaxation Oscillator
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
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 $ln\left(\frac{I_t}{I_0}\right) = -\frac{t}{RC}$ or $R = -\frac{t}{ln\left(\frac{I_t}{I_0}\right)C}$
  - All we need is the current at two times ($I_0$ and $I_t$), and the capacitance ($C$) to get the resistance $R$
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
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 in the database in many areas, we can stack results to improve signal-to-noise ratio
Resistivity Maps

Houston Area

Milam County
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.
Resistivity Volume Arizona
Resistivity Volume Cross-Section
Houston Area Resistivity Volume Example
IP (Induced Polarization) Effect

• IP Effect is the departure of measured voltage from the square wave input current

• It can be measured on either the decay curve or on the charging curve
Lightning and the IP Effect

- Lightning does not have a square waveform
- But it does have a very steep onset
- Variations in the onset as measured (rise-time) show the IP Effect
The equivalent circuit

- By treating this as charging a capacitor \((C_2)\) through a resistor \((R_3)\), an apparent capacitance can be calculated.
- From apparent capacitance a value for average permittivity can be calculated.
Permittivity Volumes Arizona
4. Examples of using lightning databases to map geology
Lightning Analysis Defines Stratigraphy

Lightning Attribute: Rate of Rise-Time
Lightning Analysis
Interprets Paleochannels and Meander Schrolls

Lightning Attributes: Surface Resistivity (left) Peak-to-Zero (right)
Lightning Analysis Correlates with Fields

Second Pass

- **Dark Red**: Production but no anomaly.
- **Black**: Anomaly correlates to production.
- **Red**: Black
- **Dark Blue**: Location Line Aids
- **Olive Green**: Black & White

**Excellent Examples**

- **Dark Blue**: Anomaly but no production.
- **Black**: Production with partial to no anomaly.
- **Black & White**: Field alignment, minimal correlation.

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A New Potential Fields Method, Supplementing Gravity & Magnetics
Michigan Basin Topography & Strike Density
Lightning Analysis - Quicker Regional Overviews
More details at Play Fairway & Prospect Scales
Imagine collecting a 3-D seismic survey here!
North Houston In-Line Animation
Texas Resistivity Fault Interpretation - 1

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Texas Resistivity Fault Interpretation - 2

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NSEM and Resistivity Volumes are a Technology Breakthrough

• Attribute maps identify lineaments related to faulting
• Resistivity and Permittivity volumes provide an independent view of geology
• Resistivity & Permittivity volumes can be created to match 3-D geometry
• Expect merger of resistivity & Permittivity volumes and lithology predictions
What we have covered:

1. NSEM - A new technology to identify geologic hazards
2. The meteorology behind lightning databases
3. Calculating resistivity volumes from lightning databases
4. Examples of using lightning databases to map geology
Find out more at

http://www.dynamicmeasurement.com/TAMU
http://www.dynamicmeasurement.com/TAMU/150122_BYU
http://www.dynamicmeasurement.com/TAMU/150122_BYU_Expanded_Presentation

Thank You!

See Lightning, think DML & solutions!
See Lightning, Think DML

• Contact Information:

• H. Roice Nelson, Jr.
  cell: 713.542.2207
  e-mail: roice@dynamicmeasurement.com

• Dr. Jim Siebert
  cell: 832.423.2355
  e-mail: jim@dynamicmeasurement.com

  ▪ www.dynamicmeasurement.com

  ▪ 2155 West 700 South #31
    Cedar City, UT 84720
    – Fax: 435.267.2668

  ▪ 211 Baker Road #382
    Barker, TX 77413
    Office: 281.579.0172
Discussion