Lightning, A Shockingly Unconventional Technology for Exploration

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Outline

NSEM - A new geophysical data type

The meteorology behind lightning databases

Examples of using lightning data to interpret geologic features
Natural Source Electro-Magnetics (NSEM)

A NEW GEOPHYSICAL DATA TYPE
Each data type triggered a step change in new revenues and cost avoidance for upstream oil and gas companies.
Proven & Patented Technology

Fig. 1

United States Patent
Nelson, Jr. et al.

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

METHOD FOR LOCATING SUB-SURFACE NATURAL RESOURCES

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G01W 1/00 (2006.01)

U.S. Cl. 324/12; 324/1.1; 324/702

See application file for complete search history.

References Cited

U.S. PATENT DOCUMENTS
Lightning Strike Measurements

- Location
- Time and Duration
- Rise Time
- Peak Current
- Polarity
- Peak-to-Zero
- Density
Resistivity & Permittivity Volumes
Easily Integrated with 3-D Seismic & Well Data
Existing Technology & Lightning Technology

- Attribute Maps
- Resistivity Volumes
- Resistivity X-Sections & Slices
- Evergreen Data
- 17 Year Database US & Canada
- 4 Year Database Worldwide
- Integrates with G&G Data
- Patented, & Patent Pending
- 2 month project turnaround
- 1% cost of 3-D Seismic

AGI Resistivity Sections
https://www.agiusa.com/index.shtml

CSEM Survey from: EMGS
http://www.emgs.com/content/870/Structural-imaging

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THE METEOROLOGY BEHIND LIGHTNING DATABASES
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) from cloud-to-cloud, so why do they strike the ground where they do?

Lightning strike locations primarily controlled by earth’s electromagnetic currents.
Lightning Maps and Natural Resources

Lightning strike density regionally controlled by meteorology, and locally controlled by terralevis (shallow earth) currents.
Why is lightning recorded?
Early Storm Warning - Safety - Insurance - Meteorology

Dead Cattle along a fence
330 Sensors Record U.S. Lightning Strike Locations
Horizontal Resolution: 650-980’ (200-300 meter)
Lightning Bypasses Tall Objects
Lightning Strikes Are Not Random!

Influenced by Lateral Changes in Rock Properties:

- Faults
- Fracture Swarms
- Anisotropy
- Pore Fluids and Salinity
- Porosity changes
- Permeability changes
- Mineralization

Upward lightning to left shows electrostatic charge builds up in the ground, as well as in the atmosphere.
EXAMPLES OF USING LIGHTNING DATABASES TO MAP GEOLOGY
Lightning Data Correlates To Geology: Salt Domes

Density map shows Lightning Strikes Cluster

Attribute map shows Salt Domes in Same Area
Lightning Data Correlates To Geology: Fluvial Depositional Patterns

Lightning Attribute
Rate of Rise-Time

Milam Co., TX

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Lightning Data Correlates To Geology: Texas Gulf Coast Regional Correlation

Lightning Strike Density

Structure & Field Outlines

Non-Random Strike Distribution

- Frio
- Wilcox
- Vicksburg
Lightning Data Correlates To Geology: Fault Patterns and Hydrocarbon Accumulations

Structure & Field Outlines

Lightning Lineations

Subsurface Faults

Lightning Strike Density

Strike/Lightning Contours

Anomaly → Partial Prod.

Anomaly → Prod.

Prod. → No Anomaly

Anomaly → No Prod.
Observations

• Lightning strikes non-random.
• Lightning strikes generally correlate to field locations.
• Faults do not appear to cut across lightning lineaments, generally striking parallel/sub-parallel to lightning features.
• Two faults show abrupt change in strike direction that closely match lightning contour patterns.
Texas Gulf Coast Conclusions

• Local geology influences where lightning strikes occur.
• NSEM has potential to locate hydrocarbons.
• NSEM has potential to delineate subsurface fault patterns.
Regional Structure Map & Field Locations
Colorado County, TX

See Lightning …
DML … think DML & solutions

Frio, Wilcox and Vicksburg Production
Lightning Data Correlates To Geology: Effective Reconnaissance Mapping
Observations

• Rise-Time lightning attribute shows non-random patterns.
• E/W trending yellow and orange faults generally separate the northern low Rise-Times from the southern high Rise-Times.
• 26 of 28 fields (93%) correlate to Rise-Time anomalies.
• Although 4 strong Rise-Time anomalies do not correlate to production, 28 of 32 (87%) of them do correlate to fields.
Colorado Co., Texas Conclusions

• NSEM identified 32 leads in study area.

• NSEM reconnaissance mapping would have justified purchase &/or acquisition of seismic data resulting in 28 prospects generated.

• NSEM reconnaissance mapping would have resulted in an 87% drilling success rate.
Lightning Data Correlates To Geology: Mineral Exploration

Lightning Attribute Map Identifies Hydrothermal Alteration Associated w. Porphyry Copper Deposit

Active Copper Mine
Pina Co., AZ

Porphyry Copper Deposit
Simplified Porphyry Copper Deposit Model
Typical Mineral Zones of a Porphyry Deposit

Conductivity anomaly surrounds more resistive ore body in center.

(after Emond, Zhdanov & Petersen, 1970)
Porphyry Copper Deposit Signature

- Multiple igneous intrusions present.
- Contact metamorphism/alteration halos.
- Inner high resistivity zone partially or completely enclosed by outer conductive zone.
Topography and Lightning Density
Pina Co., AZ
Positive Peak Current Resolution Copper Mine
Hydrothermal Alteration & Dike Interpretation
negative peak current
resolution copper mine
hydrothermal alteration & dike swarm interpretation

peak current neg.
eye altitude 39,261'

1 mile

peak current neg.
eye altitude 39,261'
3-D Resistivity Volume
Resistivity Profile Shows Porphyry Copper Signature
Inner High Resistivity & Outer Conductive Zone

Resolution Copper Mine Pinal County, AZ
Pina Co., Arizona Conclusions

• Annular lightning attribute clusters suggest lateral resistivity changes caused by igneous intrusion & hydrothermal alteration.

• Linear trends of positive & negative peak current believed to be guided by igneous dikes/sills emplaced during igneous intrusion.

• Resistivity profile shows same electromagnetic signature used by mining industry to map porphyry copper deposits.
Facts

• NSEM data can identify regional fault trends & may ultimately be capable of mapping prospect scale faults.

• NSEM has shown remarkable potential to identify hydrocarbon accumulations.

• NSEM’s ability to identify hydrothermal alteration zones demonstrates potential to map rock properties.
NSEM Overview

• NSEM can be calibrated to, & integrated with, potential field, seismic & subsurface data.

• NSEM can fill in between or extend beyond 3-D surveys & can supplement 2-D seismic data.

• NSEM cost 1/100th the cost of 3-D seismic & can be acquired, processed and interpreted within 6-8 weeks.

• Lightning data is available world-wide & can be utilized for reconnaissance mapping for frontier, new venture & exploration.
What we have covered:

NSEM - A new geophysical data type

The meteorology behind lightning databases

Examples of using lightning data to interpret geologic features
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.

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