

An Unconventional Tool for Unconventional Exploration

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ABSTRACT

WHY IS LIGHTNING TRACKED & MAPPED?

1. Natural Source Electromagnetics (NSEM) has been proven effective for petroleum & mineral resource exploration. It’s quick, inexpensive & versatile.
2. Applications include reconnaissance & detailed fault mapping, delineating hydrocarbon accumulations & mapping porphyry copper deposits.
3. NSEM analysis can be used for reconnaissance and detailed fault mapping.

NATURE OF LIGHTNING

• Lightning, what is it and why it is tracked, stacked & mapped?
• Natural Source Electromagnetics (NSEM) – a new geophysical data type.
• Example of using NSEM to map active faults.
• Conclusions.

POSTER OUTLINE

- Lightning, what is it and why it is tracked, stacked & mapped?
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- Example of using NSEM to map active faults.
- Conclusions.

LIGHTNING: an atmospheric discharge of electricity, initiating the air to create highly conductive plasma channels.

COLLECTION OF LIGHTNING DATA

National Lightning Detection Network

1. Storm tracking
2. Safety warnings
3. Insurance
4. Fire forecasting
5. Hurricane tracking
6. Research & more... Natural resource exploration!
7. Typical Texas lightning strike recorded by 16-24 sensors.
8. Sensors within 600 mi. of strikes contribute to triangulation.
9. Empirical results show location errors are reasonably dense databases 35-90.

COLLISION OF LIGHTNING DATA

- Step Leaders: intensely charged channels of divergent zig-zagging, branching electrons seeking positive ions to discharge buildup, static energy.
- Streamers: rising streams of positive charge, attracted to downward seeking electron step leaders when step leaders are within 30-300.

FAILED LIGHTNING STRIKES & STREAMERS

Streamers: rising stream of positive charge, attracted to downward seeking electron step leaders when step leaders are within 30-300.

PRIMARY LIGHTNING INFLUENCE - GEOLOGICALLY CONTROLLED TELLURIC CURRENTS

- Strike density regionally controlled by meteorology, locally influenced by geologically sourced perturbations of the Earth's telluric currents ("Terralevis" currents).
- Strike locations primarily controlled by earth's "peak current" lightning attribute.

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EACH STRIKE REPRESENTS A UNIQUE CAPACITOR

- "Peak Current", one of the lightning attributes collected worldwide, is the maximum current associated with any given lightning strike.
- Lightning is believed to be influenced by passage to a depth proportional to cloud height, as derived from the "Peak Current" lightning attribute.

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Porphyry Copper Exploration Signature
- Multiple igneous intrusions present.
- Contact metamorphism/alteration halos.
- Inner high resistivity zone partially or completely enclosed by outer conductive zone.

U.S. & Canadian Patents
Porphyry Copper Electromagnetic Signature

Lightning attribute maps are generated & interpreted similar to seismic attributes. These attribute maps have been used to identify regional & sub-regional fault patterns, hydrocarbon accumulations, salt domes, near-surface point bar deposits & porphyry copper deposits. The basis for these correlations is that lightning strike locations, the type of lightning strikes & the electrical attributes associated with each strike can be influenced by lateral inhomogeneity caused by faults, fractures, mineralization, pore fluids & salinity variations.

Formation of Porphyry Copper Deposits

1. Igneous intrusion of shallow sedimentary rocks.
2. Magma and associated hot mineral-rich fluids come in contact with host rocks & generate chemical/mineral changes creating low-grade copper mineralization.
3. Erosion strips away overburden subjacent low-grade mineralized areas to weathering.
4. Rainwater leaches Copper and redeposits it below at the water table, creating concentrations of high-grade Cu deposits.

Resolution Copper Mine Reveals Porphyry Copper Signature

3-D Apparent Resistivity Profile Through Resolution Copper Mine Reveals Porphyry Copper Signature

Note positive and negative lightning peak current contour-like anomalies partially enclosing copper orebody at Resolution Copper Mine. Patterns consistent with hydrothermal alteration zones associated with pyrite halos. Linear features correspond to igneous intrusions, typically associated with porphyry copper deposits.

Application to Mineral Exploration
- NSEM has the potential to explore for any mineral commonly found by conventional electrical geophysical prospecting techniques.
- NSEM can map subsurface electrical rock properties, structure & stratigraphy, also applicable to unconventional resource exploration.

Hydrothermal Alteration Zone/Pyrite Halo

33°17'53.73" N 111°03'17.57" W

Rise Time Rate Map
Resolution Copper, AZ

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Seismic Stratigraphy and Prospect Generation - North Houston

- Mapping subsurface features
- Calibrating to known active fault systems
- Mapping reservoir anomalies
- Prospect generation

NSEM Correlates To Geology:
Fault Patterns and Hydrocarbon Accumulations

- Low Bulk Volume Water
- Reconnaissance
- High Resistivity

These and other findings show NSEM has the potential to delineate subsurface fault patterns.

The Same Rock Properties Influencing NSEM
May Help Define Unconventional Sweetspots

- High Resistivity
- High Total Organic Carbon
- High Acoustic Impedance (brittleness)
- Low Bulk Volume Water

NSEM Correlates To Geology:
Colorado County, TX

Effective Reconnaissance Mapping
Rise Time Prospect Scale Field Correlations

- 87% of lighting attribute anomalies (Rise Time) correlate to Erwin, Vicksburg or Wilcox production.

Conclusions
- NSEM identified 32 leads in study area.
- Reconnaissance mapping would have justified seismic data follow-up resulting in the generation of 28 prospects.
- NSEM reconnaissance mapping would have resulted in an 87% drilling success rate.

Unconventional Exploration Conclusions
- NSEM can provide apparent resistivity maps of unconventional reservoirs in depth & low time for calibration to logs & seismic data.
- NSEM apparent resistivity anomalies, crosslines & arbitrary lines can tie well data & be displayed, interpreted & integrated with well logs & seismic data.
- NSEM can be used as a reconnaissance mapping tool to high-grade resistivity sweet spots for subsequent in-depth evaluation.
- NSEM can be employed in other basins in search for Austin Chalk & Eagle Ford Shale sweet spots.
- NSEM can be similarly utilized in search for sweet spots in any unconventional trend relying on resistivity as a key predictive tool.

Triangulated Fault Segments & Fault Plane Maps:
Same Interpretive Quality Control as Seismic Data

- Potential Faults, Pinchouts & Resistivity Anomaly
- Same Interpretive Quality Control as Seismic Data

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