Mapping Faults With Lightning, Natural-Sourced Electromagnetics (NSEM)

Validating NSEM with 2-D Resistivity Imaging Profiling & Ground Penetrating Radar

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Project Background

This began as a validation study to determine whether known active growth faults in the Houston, Harris County area could be identified in the subsurface with NSEM 3-D resistivity data.

Once this objective was achieved the study expanded to document how stratigraphy could be identified and even mapped from NSEM data, similar to how 3-D seismic data is interpreted.

Additional validation studies have been documented to illustrate NSEM’s full potential for application to resource exploration. These can be found in the presentation titled:

“Lightning, A Shockingly Unconventional Way to Conduct Exploration.”
Active Faults in Houston Metropolitan Area

• There are approximately 300 active & potentially active normal faults in the Houston/Harris County, TX area. Many have a surface expression & can be identified by the property damage caused by displacement across these faults.

• Some of these faults have been further documented & mapped using near surface geophysical techniques such as resistivity imaging profiling, ground penetrating radar & seismic refraction.

• NSEM data was evaluated to demonstrate its ability to identify subsurface faulting & how it could be easily integrated with conventional near surface geophysical techniques to obtain a more complete geological understanding of the subsurface.
Houston/Harris County Area Active Faults
Fault Characteristics

• The predominantly south-dipping Houston area faults are believed to be listric growth faults having near surface fault plane dips of 60-75 degrees. Down-to-the-north antithetic faults are also present.

• Faults selected for this study were three radial faults associated with the Hockley Salt Dome, located approximately 35 mi. northwest of downtown Houston. Two of these are designated faults “A” & “B” on the previous slide and are down-to-the south and west respectively. A fourth fault located south of Tomball, TX was also evaluated with NSEM.

• NSEM data used in this study consisted of resistivity profiles derived from lightning strike data. Published maps of the fault locations & 2-D resistivity image profiles were used to tie the NSEM profiles to surface fault locations.
Data Integration

- A series of profiles ("Lines") striking approximately perpendicular to the fault traces were extracted from the NSEM resistivity volume & the surface locations of the active faults were posted on each profile.

- The NSEM data is estimated to begin at 5,200’ to 5,600’ & is based on the estimated depth of lightning penetration derived from average cloud height, average peak charge of the area’s lightning strikes & an average velocity of 8,000’/sec to convert two-way resistivity times to approximate depth.

- Based on publications describing near & subsurface measurements of the area’s faults, potential subsurface fault matches to surface fault cuts were trigonometrically constrained by heave as a function of estimated fault angle versus depth relationships.
Hockley Radial Fault “A”

Resistivity profile “Line 2” displayed in next slide.
Sequence Stratigraphy & Buried Faults

Can NSEM map stratigraphy?  NSEM identifies “buried” faults.

Observed Fault Scarp
(Fault “A”) Hockley Fault

USGS Survey Marker F1254

Depth (ft)

0 60 120 180 240 300 360 420 480

USGS Survey Marker F1254

Clay/Clayey Sand

Depth (m)

33.9 36.9 39.9 42.9 45.9 48.9 51.9

SE

Increasing Resistivity

Erosional/depositional features?

Line 2

Fault “A”

SE

Line 2

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NSEM Fault Validation 9
Interpretive Ambiguity & 3-D Mapping

After M. Saribudak, Leading Edge, Feb 2011

Increasing Resistivity

Alternate structural interpretation. How reliable is this fault interpretation?

3-D NSEM mapping techniques would resolve ambiguity.

The next two slides will suggest an answer to the above question beginning with Fault “A”.

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Multiple NSEM Lines Document Fault “A”

3-D NSEM Extends 2-D Resistivity

Calibrated NSEM Builds Reliable Structural Framework

Multiple Resistivity Offsets.

3-D NSEM Enables Fault Surface & Structural Mapping.
Ground Penetrating Radar
Shallow Micro-Faulting Adjacent to Fault “A”

Reveals Fault Style Similar to NSEM Findings at Depth.

After M. Saribudak, Leading Edge, Feb 2011

Faults added by this author to augment published interpretation & to correct slippage of original fault segment overlays.
GPR & NSEM
Similar Micro/Macro Structural Styles

Horsts, Grabens & Half-Graben Structures
Hockley Radial Fault “B”

Resistivity profile Lines 1-4 displayed on next slide.
Hockley Radial Fault “B” Lines 1-4

Increasing Resistivity Consistency Tying Surface Fault & Picking As Many As Seven Faults.

Line 1

Line 2

Line 3

Line 4

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Hockley Radial Fault “C”
2-D Resistivity Imaging Fault Signature

NSEM 3-D Resistivity Duplicates
2-D Resistivity Fault Signature.

After M. Saribudak, Fast Times, Vol 17, No. 1, March 2012
Willow Creek Fault, Tomball, TX
NSEM Duplicates Resistivity Fault Signature

NSEM Overview

• NSEM resistivity volumes map shallow to deep targets, from about 2,700’ to 15,000’ depending on weathering & sub-weathering thickness, aggregate interval velocity & the area’s average lightning peak charge.

• NSEM resistivity is displayed & interpreted in 3-D fashion & easily integrated with surface geology, well data, synthetic seismograms, seismic refraction, 2-D/3-D seismic reflection & potential field data.

• To date NSEM has been used to map faults, stratigraphy & rock properties & to identify hydrocarbon accumulations.

• At a minimum, NSEM is a cost effective reconnaissance tool that can be acquired, processed and interpreted for 1% of the cost of 3-D seismic data.
For questions regarding:

• Proprietary NSEM Sales
• Project Design
• Project Management
• NSEM & Geoscience Data Integration
• Seismic Interpretation
• Exploration, Exploitation or New Ventures

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