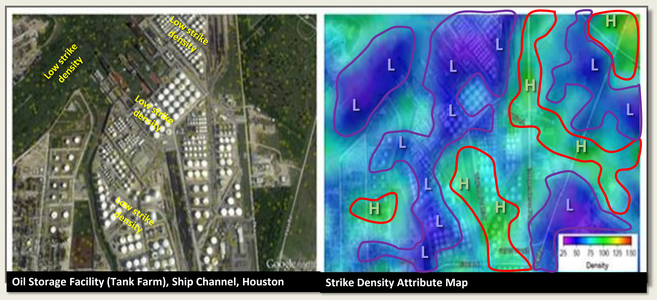
Mapping Subsurface Faults with Lightning and Resistivity

DOES INFRASTRUCTURE CONTROL LIGHTNING?

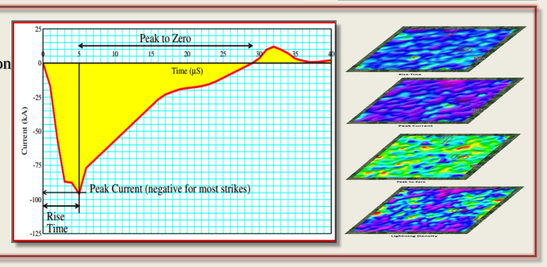
APPROXIMATELY 60% of TANK FARM EXPERIENCED LOW STRIKE DENSITY



LIGHTNING BYPASSES TALL OBJECTS AND INFRASTRUCTURE EXPECTED TO ATTRACT LIGHTNING

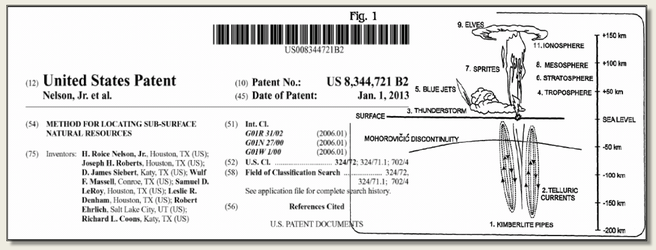
LIGHTNING STRIKE MEASUREMENTS ⇨ ATTRIBUTE MAPS

- Location
- Time & Duration
- Rise Time
- Peak Current
- Polarity
- Peak-to-Zero
- Density



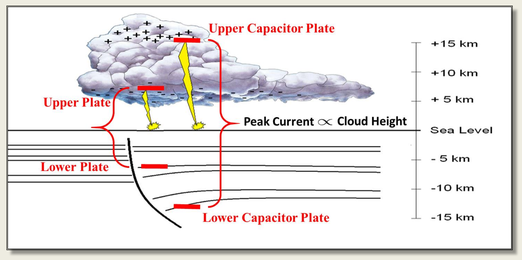
Lightning attribute maps are generated & interpreted similar to seismic attributes. These attribute maps have been used to identify regional & sub-regional fault patterns, hydrocarbon accumulations, salt domes, near-surface point bar deposits & porphyry copper deposits. The basis for these correlations 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.

NATURAL SOURCE ELECTROMAGNETICS (NSEM) - A NEW GEOPHYSICAL DATA TYPE



PROVEN & PATENTED TECHNOLOGY FOR LOCATING SUBSURFACE NATURAL RESOURCES

THE BASIS FOR CALCULATING 3-D APPARENT RESISTIVITY AND ATTRIBUTE VOLUMES



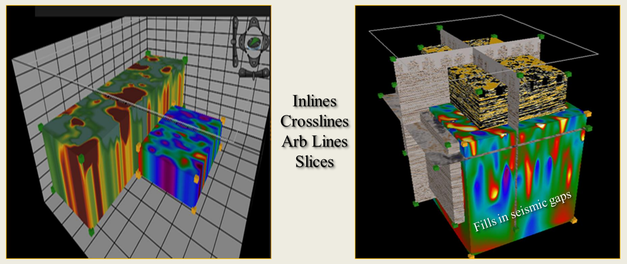
Millions of lightning strikes grouped by peak current.

Strike data therefore grouped by depth.

Provides basis for generating 3-D apparent resistivity volumes.

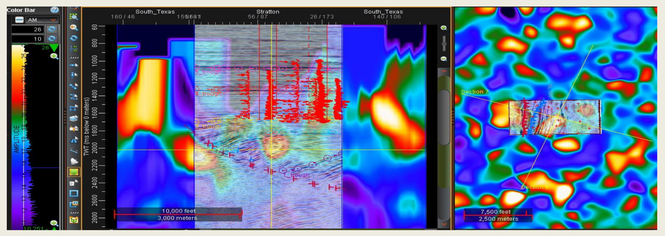
Based on the Earth's capacitor model, this illustration depicts how subsurface variation in electrical rock properties can interact with & perturb telluric currents. The depths of electrical interaction & hence its affect on lightning is proportional to the strength of each lightning strike. Peak current is measured & from this attribute cloud height (the top of the capacitor) is calculated. The data is "stacked", sorted by peak current (depth), interpolated & used to generate 3-D attribute volumes.

3-D DATA VOLUMES DERIVED FROM LIGHTNING



Resistivity, permittivity and all measured and calculated lightning attributes can be used to generate 3-D data volumes, all of which are easily integrated with 3-D Seismic & well data.

SEISMIC, SUBSURFACE, NSEM DATA INTEGRATION



Seismic overlay on apparent resistivity profile with seismic and resistivity time slices to right. interpreters can display well logs, synthetic seismograms, seismic & resistivity profiles along any line, trace or arbitrary line direction for data integration and interpretation.

ROCK STRESS ELECTROMAGNETIC SIGNAL THEORY

The next series of images represent the culmination of theoretical, field & laboratory work of Dr. Friedemann Freund, who has formulated and written extensively about his Rock Stress Electromagnetic Signal Theory.

Dr. Freund's findings provide independent support for Dynamic Measurement's empirical field results and theoretical argument linking geology to lightning strike patterns and lightning attributes.

Dr. Freund is affiliated with the NASA Ames Research Center, the Carl Sagan Center and the SETI Institute, located in Mountain View, CA and the Department of Physics at San Jose State University, San Jose, CA.

Dr. Freund's theory will now be applied to the field of Natural Source Electromagnetics.

STRESS-INDUCED CURRENTS IN THE LABORATORY

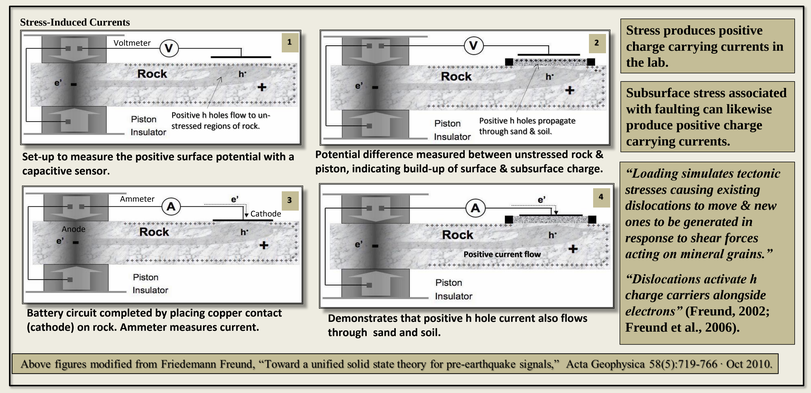
Although silicate minerals are primarily insulators, most can behave as semiconductors because they contain dormant electronic charge carriers, i.e. electricity that can be activated by stress.

When rocks are subjected to stress, first positive and then negative charge carrying currents are produced (positive or "h holes" and electrons respectively).

These stress-induced currents flow toward the unstressed region of rock samples and from the interior to the rock's exterior, ultimately ionizing the air.

Thus, faulted areas offer a plentiful supply of dormant charge carriers that when triggered by the attraction of overhead storm clouds, can provide the necessary current flow, in the form of "streamers," to attract opposite charged step-leaders.

STRESS PRODUCES A ROCK BATTERY IN THE LAB



Stress produces positive charge carrying currents in the lab.

Subsurface stress associated with faulting can likewise produce positive charge carrying currents.

"Loading simulates tectonic stresses causing existing dislocations to move & new ones to be generated in response to shear forces acting on mineral grains."

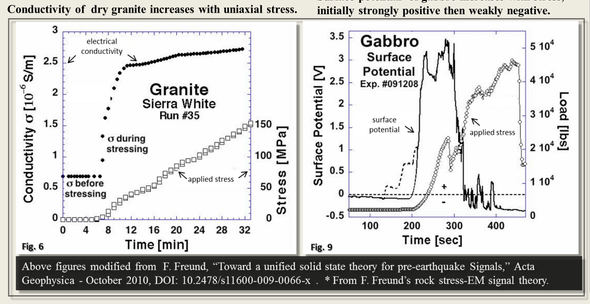
***"Dislocations activate h charge carriers alongside electrons"* (Freund, 2002; Freund et al., 2006).**

Above figures modified from Friedemann Freund, "Toward a unified solid state theory for pre-earthquake signals," Acta Geophysica 58(5):719-766 · Oct 2010.

STRESS-INDUCED CHANGES OF ELECTRICAL ROCK PROPERTIES IN GRANITE & GABBRO

- **Creation of dormant charge carriers.**
- **Localized electrical currents generated.**
- **Provides reservoir of positive and negatively charged particles.**
- **Streamers capable of influencing lightning.**

Conductivity of dry granite increases with uniaxial stress. **Surface potential of gabbro increases with stress, initially strongly positive then weakly negative.**



Above figures modified from F. Freund, "Toward a unified solid state theory for pre-earthquake Signals," Acta Geophysica - October 2010, DOI: 10.2478/s11600-009-0066-x . * From F. Freund's rock stress-EM signal theory.

Recent studies by F. Freund suggest that stress-induced increases in conductivity & the generation of positive & negative currents & surface potential, are not solely influenced by improved grain-to-grain contacts.

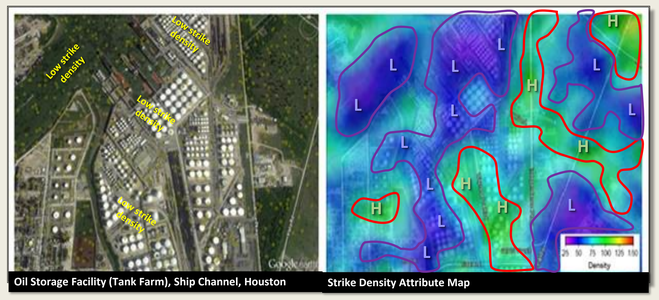
It is likely that changes in electrical rock properties are caused by an increase in the number of electrons, negative ions & positive hole charge carriers produced when rock volumes are stressed.

Louis Berent, Dynamic Measurement, LLC., Houston, TX
ljberent@dynamicmeasurement.com, 832 352-3795

Mapping Subsurface Faults with Lightning and Resistivity

DOES INFRASTRUCTURE CONTROL LIGHTNING?

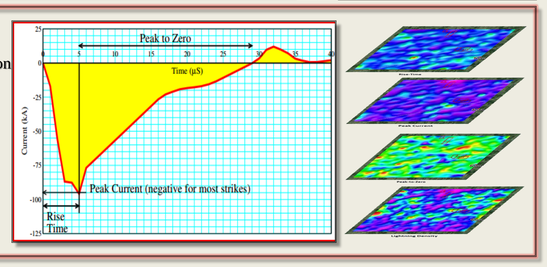
APPROXIMATELY 60% of TANK FARM EXPERIENCED LOW STRIKE DENSITY



LIGHTNING BYPASSES TALL OBJECTS AND INFRASTRUCTURE EXPECTED TO ATTRACT LIGHTNING

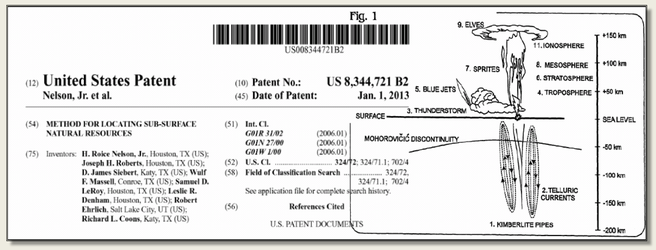
LIGHTNING STRIKE MEASUREMENTS ⇨ ATTRIBUTE MAPS

- Location
- Time & Duration
- Rise Time
- Peak Current
- Polarity
- Peak-to-Zero
- Density



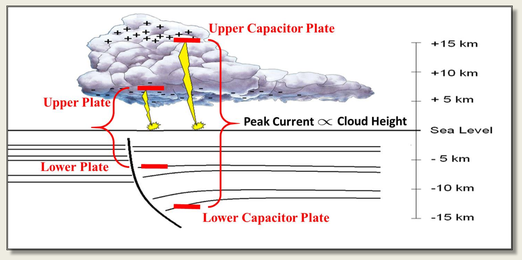
Lightning attribute maps are generated & interpreted similar to seismic attributes. These attribute maps have been used to identify regional & sub-regional fault patterns, hydrocarbon accumulations, salt domes, near-surface point bar deposits & porphyry copper deposits. The basis for these correlations 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.

NATURAL SOURCE ELECTROMAGNETICS (NSEM) - A NEW GEOPHYSICAL DATA TYPE



PROVEN & PATENTED TECHNOLOGY FOR LOCATING SUBSURFACE NATURAL RESOURCES

THE BASIS FOR CALCULATING 3-D APPARENT RESISTIVITY AND ATTRIBUTE VOLUMES



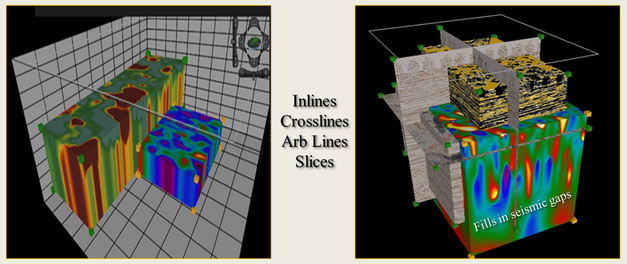
Millions of lightning strikes grouped by peak current.

Strike data therefore grouped by depth.

Provides basis for generating 3-D apparent resistivity volumes.

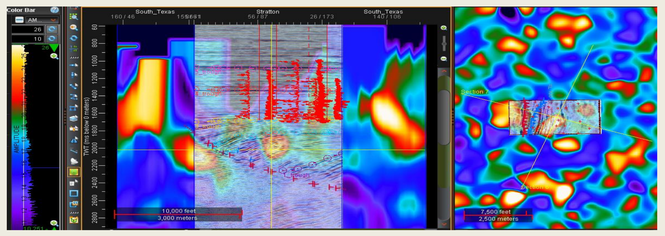
Based on the Earth's capacitor model, this illustration depicts how subsurface variation in electrical rock properties can interact with & perturb telluric currents. The depths of electrical interaction & hence its affect on lightning is proportional to the strength of each lightning strike. Peak current is measured & from this attribute cloud height (the top of the capacitor) is calculated. The data is "stacked", sorted by peak current (depth), interpolated & used to generate 3-D attribute volumes.

3-D DATA VOLUMES DERIVED FROM LIGHTNING



Resistivity, permittivity and all measured and calculated lightning attributes can be used to generate 3-D data volumes, all of which are easily integrated with 3-D Seismic & well data.

SEISMIC, SUBSURFACE, NSEM DATA INTEGRATION



Seismic overlay on apparent resistivity profile with seismic and resistivity time slices to right. interpreters can display well logs, synthetic seismograms, seismic & resistivity profiles along any line, trace or arbitrary line direction for data integration and interpretation.

ROCK STRESS ELECTROMAGNETIC SIGNAL THEORY

The next series of images represent the culmination of theoretical, field & laboratory work of Dr. Friedemann Freund, who has formulated and written extensively about his Rock Stress Electromagnetic Signal Theory.

Dr. Freund's findings provide independent support for Dynamic Measurement's empirical field results and theoretical argument linking geology to lightning strike patterns and lightning attributes.

Dr. Freund is affiliated with the NASA Ames Research Center, the Carl Sagan Center and the SETI Institute, located in Mountain View, CA and the Department of Physics at San Jose State University, San Jose, CA.

Dr. Freund's theory will now be applied to the field of Natural Source Electromagnetics.

STRESS-INDUCED CURRENTS IN THE LABORATORY

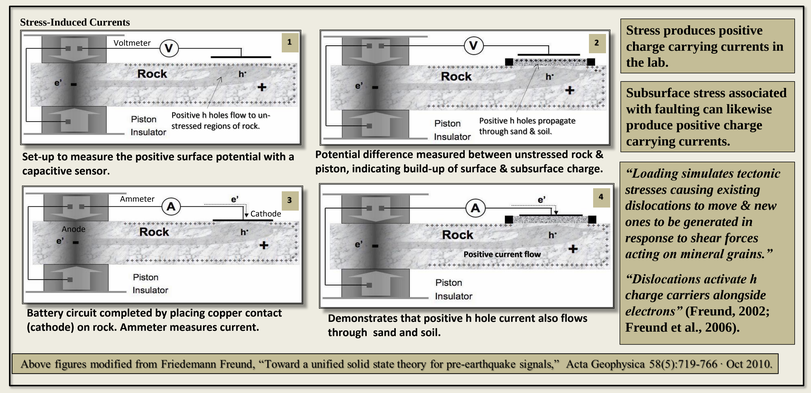
Although silicate minerals are primarily insulators, most can behave as semiconductors because they contain dormant electronic charge carriers, i.e. electricity that can be activated by stress.

When rocks are subjected to stress, first positive and then negative charge carrying currents are produced (positive or "h holes" and electrons respectively).

These stress-induced currents flow toward the unstressed region of rock samples and from the interior to the rock's exterior, ultimately ionizing the air.

Thus, faulted areas offer a plentiful supply of dormant charge carriers that when triggered by the attraction of overhead storm clouds, can provide the necessary current flow, in the form of "streamers," to attract opposite charged step-leaders.

STRESS PRODUCES A ROCK BATTERY IN THE LAB



Stress produces positive charge carrying currents in the lab.

Subsurface stress associated with faulting can likewise produce positive charge carrying currents.

"Loading simulates tectonic stresses causing existing dislocations to move & new ones to be generated in response to shear forces acting on mineral grains."

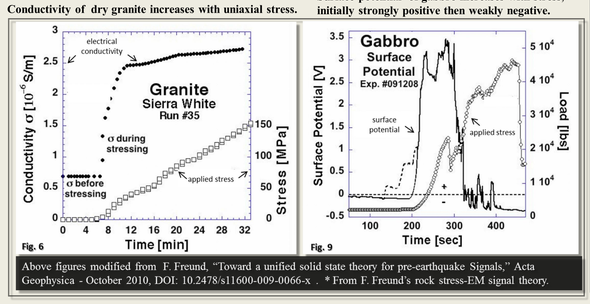
***"Dislocations activate h charge carriers alongside electrons"* (Freund, 2002; Freund et al., 2006).**

Above figures modified from Friedemann Freund, "Toward a unified solid state theory for pre-earthquake signals," Acta Geophysica 58(5):719-766 · Oct 2010.

STRESS-INDUCED CHANGES OF ELECTRICAL ROCK PROPERTIES IN GRANITE & GABBRO

- **Creation of dormant charge carriers.**
- **Localized electrical currents generated.**
- **Provides reservoir of positive and negatively charged particles.**
- **Streamers capable of influencing lightning.**

Conductivity of dry granite increases with uniaxial stress. **Surface potential of gabbro increases with stress, initially strongly positive then weakly negative.**



Above figures modified from F. Freund, "Toward a unified solid state theory for pre-earthquake Signals," Acta Geophysica - October 2010, DOI: 10.2478/s11600-009-0066-x . * From F. Freund's rock stress-EM signal theory.

Recent studies by F. Freund suggest that stress-induced increases in conductivity & the generation of positive & negative currents & surface potential, are not solely influenced by improved grain-to-grain contacts.

It is likely that changes in electrical rock properties are caused by an increase in the number of electrons, negative ions & positive hole charge carriers produced when rock volumes are stressed.

Louis Berent, Dynamic Measurement, LLC., Houston, TX
ljberent@dynamicmeasurement.com, 832 352-3795