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# Does Lightning Strike Twice?

**Lightning analysis provides a new geophysical technique, which is safe and cost-effective and has the potential to spark a step change in the geophysical exploration for oil and gas and minerals.**

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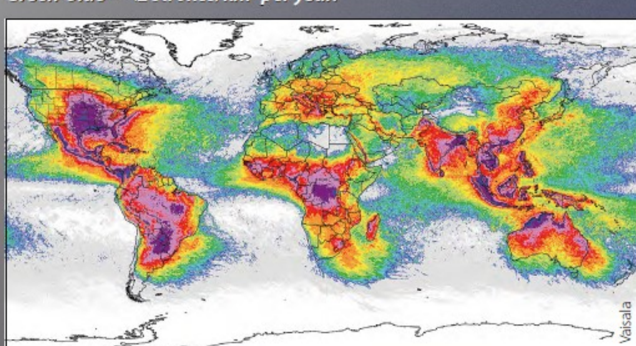
### Near Death Experiences

Benjamin and William Franklin risked their lives when conducting their famous lightning experiment in Philadelphia in 1752. A simple silk kite was sent aloft in a storm. A wire at the top served as a lightning rod. The kite was connected to a hemp string – which when wet would conduct any electrical charge from the storm down to a metal key. As the hemp line became wet, they noticed loose threads of the hemp string standing erect. Benjamin touched the key, and as the negative charges in the metal were attracted to the positive charges in his hand, he felt a spark. This experiment did not discover electricity, but it clearly demonstrated the connection between lightning and electricity.

Dynamic Measurement's path to discovery similarly took a path less travelled. Joe Roberts accidently put his life on the line while hunting ducks on his property on the edge of the Hockley Salt Dome in southern Texas, when a lightning strike hit very close to him, terrifying him. The same thing happened a year later, in exactly the same place. He drove round to his friend Roice Nelson, geophysicist and co-founder of Landmark Graphics Corporation, and asked, "Does lightning strike twice in the same place; if it does, does it mean I have oil on my property?" Roice asked Dr. Jim Siebert, Chief Meteorologist at Fox News in Houston, the same questions. Discussions with other experienced geophysicists,

*Stroke density map: lightning is a worldwide source. Pink-purple = 16->32 strokes/km² per year. Green-blue = <2 strokes/km² per year.*



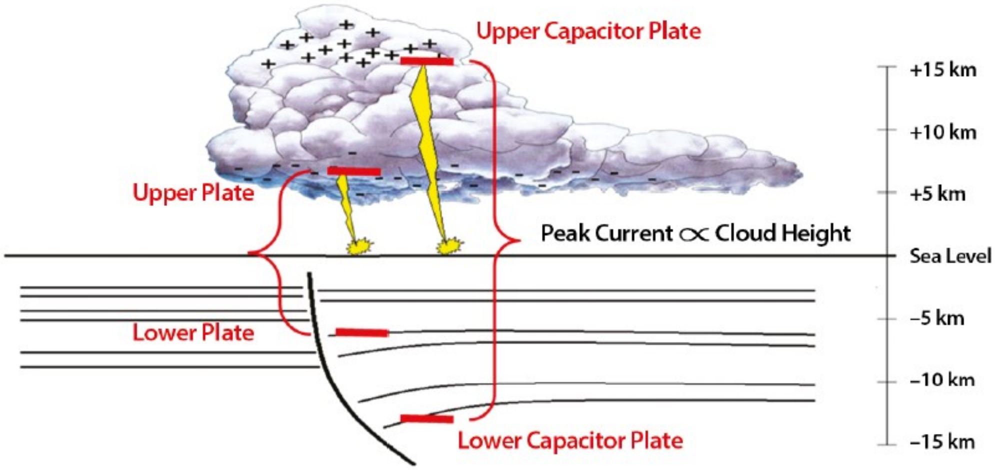



*Figure 1: A model of how lightning strikes jump across a natural capacitor, created by currents in the atmospheric and lithospheric electrical half-spaces.*

including Les Denham, resulted in the formation of Dynamic Measurement LLC.

We have now conclusively demonstrated that lightning does strike the same place twice. In fact, lightning strikes cluster, and these clusters are somewhat consistent over time. Dynamic Measurement continues to discover relationships between lightning strikes and resistive natural resources like aquifers, geothermal deposits, oil and gas reserves, as well as conductive materials like copper, gold, sulphides, clays and brines. Neither repetitive strike locations nor the presence of resistive/conductive actors under them are random.

For clarity: the entire lightning path is generally referred to as a stroke, while the location the stroke hits the ground is the strike.

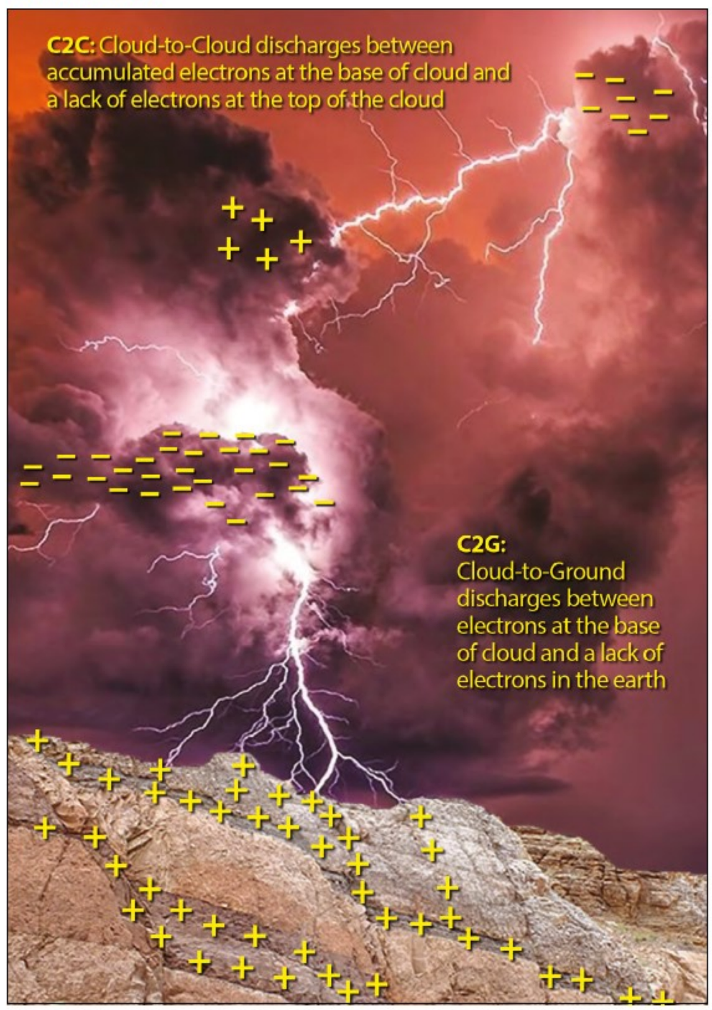
### Lightning Strikes

On a clear day the earth's surface acts as an equipotential surface, with equipotential lines parallel to the topography. Electrons cluster at a point, like an antenna – or Benjamin Franklin's kite. We are connected to the earth's electrical circuit, and the equipotential lines go up around us or the lightning rod. The electric field lines are always perpendicular to these equipotential lines.

As charge builds up in the atmosphere in an electrical storm, at the micro-scale close to the earth static electricity moves along field lines and bleeds into the earth. At the macro scale, ice and dust particle collisions within the clouds at 600–900m above the earth's surface generate electrical charges. Cloud-to-cloud (C2C) strikes result when opposite electrical charge build-ups in the clouds exceeds the dielectric, the electrical insolation of the air.

A basic assumption is that this build-up of charge interacts with telluric (earth) currents, at depths proportional to the height of the clouds where the charge originates. The atmospheric electromagnetic half-space mirrors the earth's electromagnetic half space (Figure 1). As the static charge builds up in the clouds, it interacts with and induces telluric currents. A signal with a period of 24 Hz is generally believed to have a skin depth of 600–800 km. Lightning strikes are understood to have a skin depth of a few metres. We know lightning strikes are a major source for charging telluric currents, all the way to the Mohorovičić discontinuity, at the base of the crust at a depth of 10–90 km, and everything below it is believed to be molten, and therefore a good conductor. Lightning storms build up over hours, lightning strikes over milliseconds, and this build-up of static electricity in the atmosphere is what charges telluric currents, and what interacts with these currents to guide lightning strike locations.

*Figure 2: Lightning strokes occur when there is a sufficient static charge build-up for electrical currents to jump to an area with an opposite charge, either as a C2C or C2G stroke.*



Geophysicists have known atmospheric static currents charge telluric currents since the 1950s, with the invention of magnetotellurics as a geophysical exploration technique. The build-up to a lightning strike takes up to 500 ms and can be derived by summing the time for related Cloud-to-Cloud (C2C) and Cloud-to-Ground (C2G) strikes. This build-up of atmospheric charge identifies an area of opposite charge in the subsurface of the earth. Lightning stroke pathways are largely determined by the field lines connecting these two 'capacitor plates' (Figure 2).

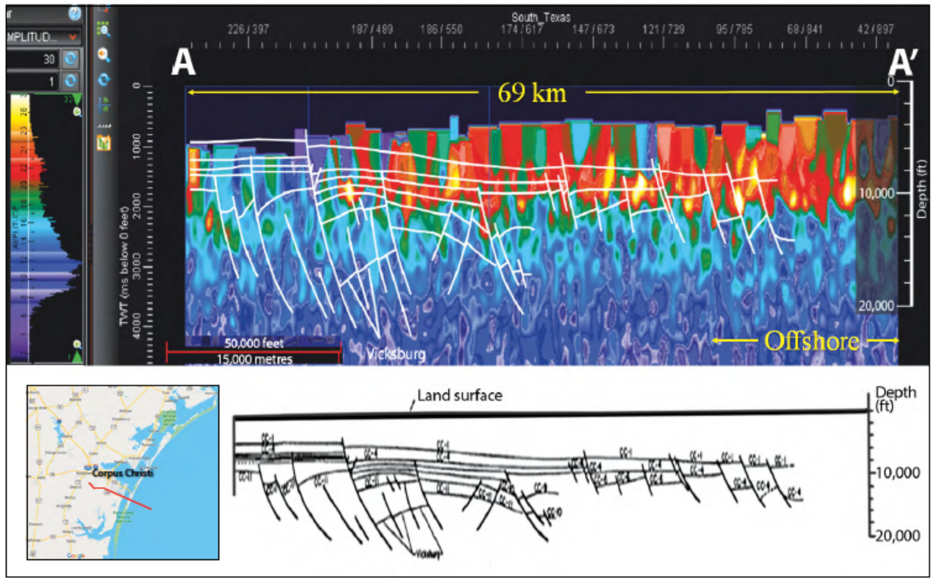



*Figure 3: Comparing 2017 lightning-derived apparent resistivity cross-section with the equivalent 1986 interpretation by Tom Ewing (BEG) based on seismic and log data demonstrates how well the 1986 interpretation matched patterns in the apparent resistivity cross-sections.*

## Earth as Capacitor

Meteorologists have studied atmospheric electrical currents for decades, although the fluid nature of the atmosphere makes measuring electric fields and equipotential surfaces in and around clouds difficult. The electrical conductivity of air is 0.3–0.8 x $10^{-14}$ Siemens per metre, considerably lower than the earth's: assuming a typical sedimentary rock has 5% porosity, the electrical conductivity is 5.0 x $10^{-4}$ Siemens per metre, or about $10^{10}$ times the conductivity of air.

Treating the atmosphere and the earth as a capacitor, the charged thunder cloud is one plate, while the other is the earth underlying the cloud. The dielectric is the insulating medium between the capacitor plates that transmits electrical force without conduction; namely the air and the earth, between the atmospheric static charge build-up and the interacting and oppositely charged currents in a different part of the thunderclouds (C2C strokes) or telluric currents at depth (C2G strokes), as in Figure 1. Dynamic makes two assumptions: firstly, lightning occurs when there is sufficient charge to bridge the capacitor; and secondly, lightning is affected by geology to a depth proportional to the cloud height, as estimated from the Peak Current of the stroke. We recognise it is hard to accurately measure the height of a lightning stroke, and that the lightning strike itself, lasting microseconds, is a small part of the electrical interaction between the atmosphere and the lithosphere.

Lightning is like a current along a wire, inducing a magnetic field, which interacts with telluric currents deep in the subsurface. These telluric currents have more impact on lightning strike locations than vegetation, infrastructure, or topography.

The North American Lightning Detection Network, containing 20 years of data from the US and Canada, is the most extensive lightning database available, with records of location, time, Peak Current, Peak-to-Zero Time, recording quality, and other attributes. Most strikes in the US are recorded by 10–25 sensors, each within about 1,000 km of the strike location. These data are collected and stored for insurance, safety, and meteorological reasons, but Dynamic Measurement's exclusive data licence for natural resource exploration highlights new uses for them.

To illustrate how lightning analysis can be used in hydrocarbon exploration, let's look at an example from the Corpus Christi area of South Texas.

## Lightning Maps for Exploration

Figures 3 and 4 compare regional lightning analysis results with geological ground truth, using work by Tom Ewing at the Bureau of Economic Geology (BEG). Dynamic Measurement has patented a method of calculating apparent resistivity from the lightning databases as a direct calculation, not an inversion process. The mathematical model is based on a relaxation oscillator (a neon light tube), where a capacitor is in series with a resistor and in parallel with a spark gap. As an input voltage is built up on the capacitor, it creates a spark across the gap, causing the inert gas to fluoresce. With a lightning strike, there is an additional resistor between the capacitor and the spark gap: namely the apparent resistivity of the earth between the strike location and where the telluric currents form the base plate of the capacitor.

Lightning occurs when the voltage across the atmospheric capacitor exceeds the dielectric strength of the air. As lightning leaders come down from the clouds, opposite charged electricity at the surface of collects and moves upward as a streamer of the opposite charge, and the up-going streamer and the down-going lightning stroke meet, the path is ionised and there is almost no resistance. The resistance in the subsurface is approximately constant over long periods of time, so even though each storm is unique and atmospheric factors vary with each stroke, with millions of strikes the consistent geological electrical properties result in strikes and attributes clustering.

Estimating the top capacitor 'cloud height' from Peak Current provides an estimate of the base capacitor depth. Placing the calculated apparent resistivity (or other lightning attributes) at these depths and doing a 3D interpolation allows the creation of an apparent resistivity (or other lightning attribute) volume. These volumes can be interpolated to provide a trace for each bin in an existing or planned 3D seismic survey or each grid point in an aeromagnetic survey, and can be loaded into a geological, engineering, or seismic interpretation workstation. Binning and averaging all resistivity or other lightning attribute values for a specific area creates a map of the sum of the specific lightning attribute or rock property being evaluated.

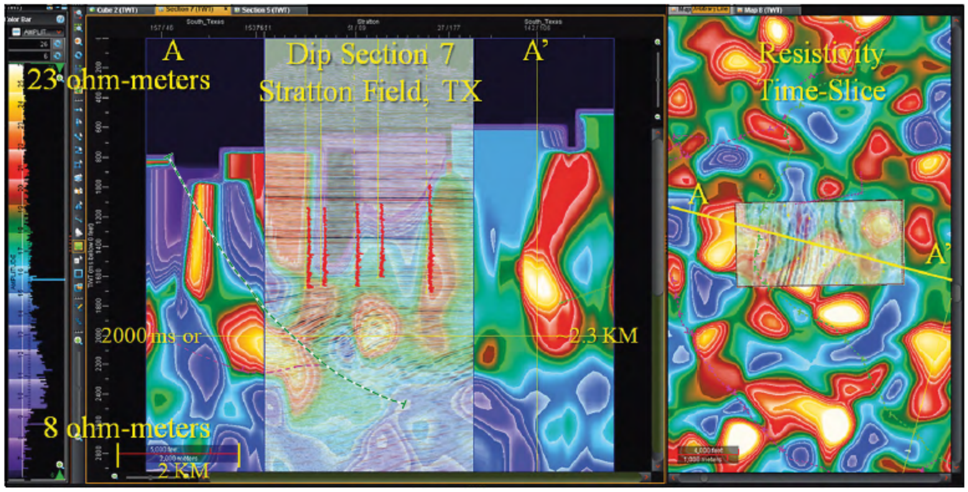



*Figure 4: Apparent resistivity cross-section through the BEG's Stratton 3D seismic survey.*

These volumes or maps, created anywhere there is Rise-Time, Peak Current, and Peak-to-Zero lightning strike data, can fill the gap between existing seismic and geophysical control. In the case of apparent resistivity, measurements are not limited to a few inches from the well bore, as with well resistivity logs.

A cross-section and a horizontal slice through the Stratton Field are shown in Figure 4, about 30 km west of section A–A' in Figure 3. In this display the seismic data, released by the BEG, is semi-transparent, revealing the apparent resistivity underneath. A Vicksburg expansion fault (dashed green line) is easy to see on the seismic data: note how well the resistivity volume maps this fault out from the seismic control. The fault can also be seen on the 2,000 ms time-slice on the right.

An apparent resistivity cross-section from south-south-west to north-north-east cutting the south-east corner of the Stratton 3D seismic survey is shown in Figure 5. This cross-section connects two deep resistivity logs, demonstrating how well the 20 ohm-metres recorded on the well log matches the 23 ohm-metres shown on the apparent resistivity colour scale on the left.

## A New Geophysical Data Type

Dynamic Measurement has been developing this new branch in the geophysical services industry for ten years. As with any new geophysical data type, we regularly find further strengths and correlations. The approach has provided results which tie lightning analysis to seismic, air mag, and other geophysical and geological control, in areas ranging from the deserts of southern California to the swamps of Florida, and from South Texas to North Dakota. Each lightning analysis project Dynamic has done so far has shown similar correlations between the lightning derived maps and volumes and available geological and geophysical control.

Geology does not change over the timeframe of building the lightning database. Unlike other potential field methods, where sources and receivers are deployed to collect data, this approach is passive and non-invasive. The source is natural: no lightning strikes, no data. The receivers are in place for other reasons, so instead of thousands of receivers and sources, there are a few receivers collecting data from millions of lightning strikes, using the most powerful electromagnetic source on earth and creating consistent and useful data. Lightning analysis projects are quicker, safer and less expensive than any other geophysical data type: no permitting, no notifications, no need for any rights-of-entry, and no boots on the ground. Results are provided in workstation-friendly formats for easy integration with other geophysical or geological data.

Lightning analysis provides a new geophysical data type. Like new geophysical data types before, this innovative branch in the geophysical services industry has the potential to spark a step change in new revenues and cost avoidance for oil and gas, geothermal, aquifer, mineral, and other natural resource exploration companies.

*An extended version of this article and references are available on geoexpro.com* ■

*Figure 5: Apparent resistivity cross-section through two deeper wells, with resistivity logs for calibrating apparent resistivity.*