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Lightning, A New Key For Pipeline Protection

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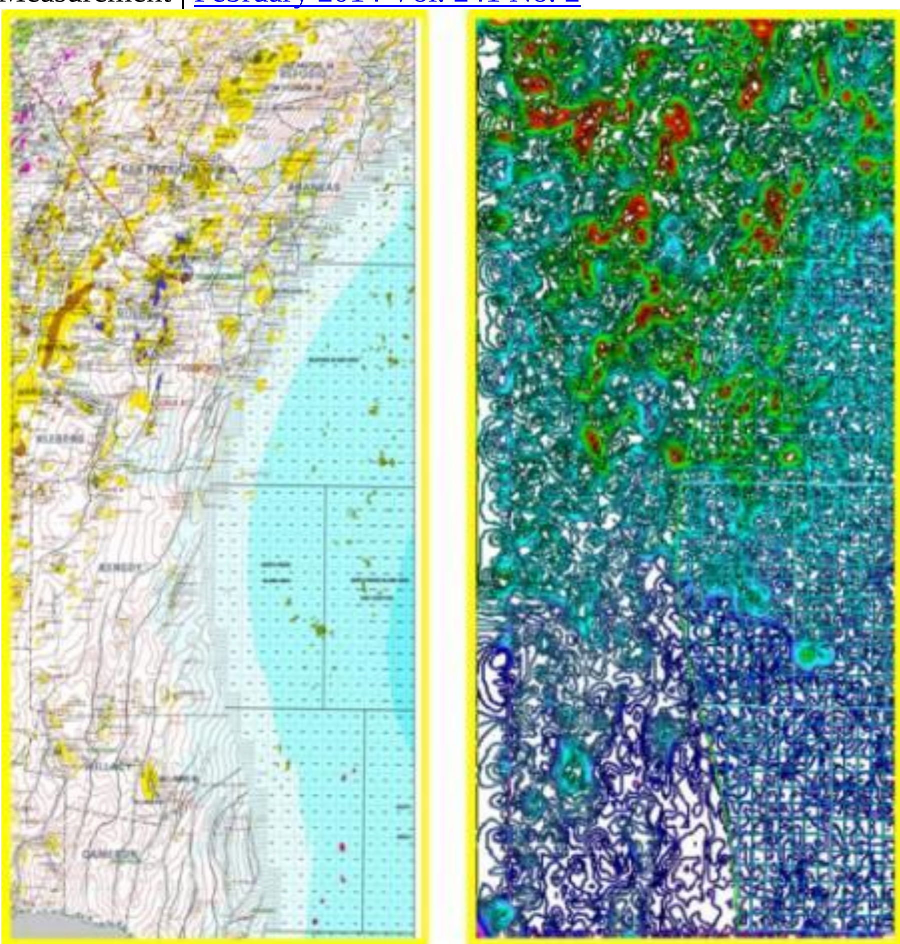


Figure 1: South Texas oil fields, left, and lightning density contours – trends continue out into the Gulf of Mexico.

In the past, it was thought that lightning strikes were random or due to an object being tall or located at a higher elevations. New discoveries are showing these are seldom the controlling factors and that geology plays a greater role. Fault lines tend to be struck by lightning more often, and it's known that active fault zones are good for oil and natural gas exploration, but can be bad for pipelines.

This is where seeps and traps often occur, but fault movement can wreak havoc on pipelines used to get these same resources to market. It appears this may be just the tip of the iceberg in the relationship between faults and pipelines. The implications of Earth electrical currents associated with faults and the impact on the pipeline industry are quite literally shocking.

Lightning Strike Data

To understand, we have to go back to June 1752 when Benjamin Franklin used a kite as a low-tech method to uncover the mysteries of lightning2. Since that time and especially over the past decade, technological advances have revealed extensive information about lightning, and those secrets are changing industries, including oil and gas exploration, mining, water and aquifer, electrical line management, and now . . . pipelines.

Lightning-strike data has become a new geophysical data type being used for natural resource exploration[4]. In January 2013, a United States patent was granted to Dynamic Measurement, LLC (DML) for a method to use lightning data to help find oil, gas, water, minerals and other natural resources[3]. New discoveries are showing this technology is going to affect a number of industries.

Lightning has been a recognized problem for energy services companies, as shown by a study of 242 storage tank accidents in which 80, or 33% were caused by lightning[1]. Now it appears lightning may be the key to understanding some problems, which in the past, have seemed unrelated. Cloud-to-ground (c2g) lightning strikes may be making certain pipeline locations more prone to corrosion and other costly nuisances.

Faults are electromagnetic hot zones where electrical currents from the atmosphere are interacting with the subsurface currents called “telluric” or “Earth currents.” All of this is detrimental for pipelines and storage facilities, as well, and lightning is a new key to understanding how to identify what areas need to have additional cathodic protection.

Roice Nelson is a co-founder of DML and was also a co-founder of Landmark Graphics Corporation, which was another industry game-changer for oil and gas exploration. He was instrumental in designing and building the first stand-alone 3D seismic interpretation workstations and thinks this new lightning technology will be an even bigger innovation. He said in order to understand how this technology works, we need to first understand some new discoveries about lightning.

“Lightning strike locations tend to cluster; those clusters tend to be somewhat consistent over time. The strike locations appear to be controlled more by geologically driven Earth currents than by topography, or by vegetation, or by infrastructure,” he said. “We have found lightning strikes with specific attributes are prone to concentrate along faults line or within specific fault blocks.”

In other words, c2g lightning strikes, which form due to meteorological reasons, are more inclined to hit the ground where these electromagnetic hot zones are located. DML is identifying these hot zones for exploration and the company’s client list is growing quickly. A recent discovery indicates that lightning analysis works out at between 200-300 feet of water in which geology is the only influence since there is no difference in ocean elevation (Figure 1).

Once beyond 300 feet of depth the influence of geology is weakened due to the water separation between the ground and the atmosphere. A foot of snow has about the same influence on lightning strikes as 300 feet of water.

What ties all of this together? Looking at the bigger picture, charged particles from the sun enter the Earth's atmosphere and charge the ionosphere and magnetosphere. Electrical currents move deep underground, specifically at the Mohorovičić Discontinuity (moho) and in waves of molten nickel and iron in the liquid outer core. The ionosphere and the charged moho and related rocks together act as a giant capacitor (storage area). Lightning normalizes this capacitor, bridging the atmospheric dielectric.

Earth Currents

Earth currents also occur in shallower stratigraphic layers from 5,000-30,000-foot depths. These currents are largely controlled by the deeper telluric currents from the moho and outer core. When these subsurface Earth currents, which might travel along a conductive shale or brine filled sandstone layer, come in contact with a fault, they begin to run along the fault line.

The current increases as additional currents run into the line and get trapped charging specific fault blocks. Lightning forms when "dart leaders" descend below a thunderstorm, which typically are between 10,000-25,000-foot elevations, seeking a connection to Earth currents. The leaders almost look like fingers reaching toward the ground, and the flash of a lightning strike forms when a connection is made.

What DML is doing could not have been done 10 years ago. This greater understanding of lightning is a direct result from technological advances that allow scientists to almost dissect each bolt. A single lightning strike can travel 150 miles, cloud-to-cloud, prior to becoming a cloud-to-ground (c2g) lightning strike. Earth currents appear to be the strongest determinant as to the physical location of c2g strikes.

In the continental United States, each strike location is measured within 100-500 feet. Measured attributes include the polarity, whether the strike is negative or positive, the rise-time from no energy to total intensity, the peak current, the peak-to-zero –the time in microseconds from the peak current to the end of the strike – the number of sensors recording the strike and several quality measurements.

Every lightning bolt has a unique signature that can be measured, compared statistically and analyzed. When bad data has been cleaned out of the database and strike locations or strike attributes are mapped, there are patterns that merge, including lineaments, which relate to faulting.

"It's only been recently that we've realized the Earth is one electrical system, and we now know that lightning strikes are not random events, but are giving us important clues to what's happening in the subsurface," Nelson said. "Most scientists think we're crazy when we first introduce them to our lightning exploration concepts, but they almost always leave saying 'this will change how the world looks at lightning.'"

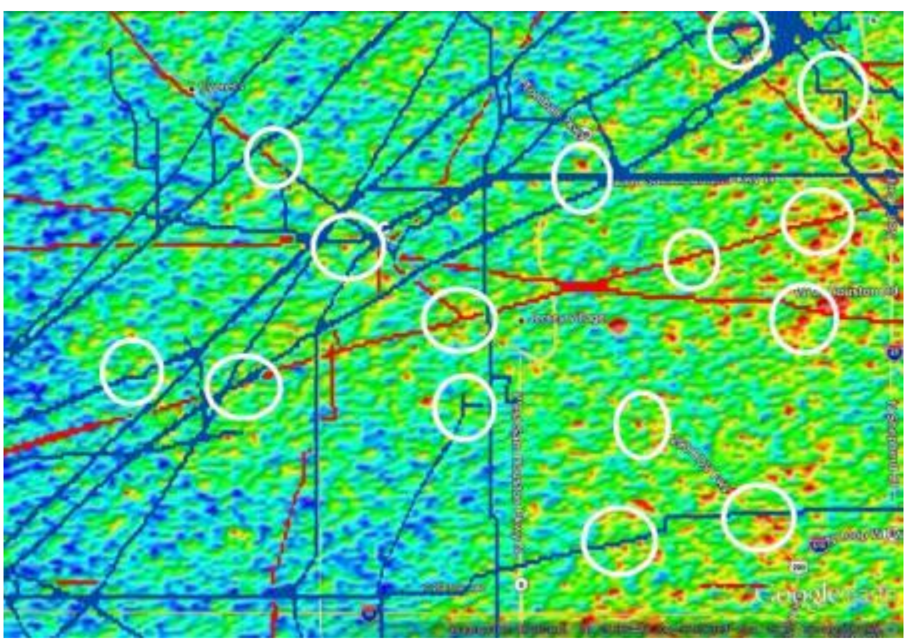
Resistivity Measurements
The exploration industry has used resistivity measurements as an exploration tool ever since the Schlumberger brothers tested their first down-hole resistivity tool in 1927. Since that time dozens of different geophysical tools have been developed for measuring resistivity, including magnetotellurics, electromagnetics, laser magnetometers and ultra-high-resolution (UHR) aeromagnetics.

Now, we are discovering lightning strikes are responding to the electrical currents in the Earth, which currents are modified by things resistive – oil, gas, water, salt, some faults – and things conductive – minerals (copper, iron, gold, silver, lead, zinc, rare earths, etc.

Lightning-strike location and attribute map patterns are impacted by zones of resistivity and conductivity, and especially when integrated with other geological and geophysical data can be used to make scientifically based predictions (measured and repeatable) about subsurface geology and geologic features like faults.

Pipelines
So why are faults bad for pipelines beyond the effect of being struck by a powerful bolt? The researchers at DML propose it's because the Earth currents are eating away at pipelines and speeding up corrosion.

In addition, these geomagnetically induced currents or GIC hot zones are also affecting pipelines and even power lines by creating interference with the flow of electricity at the surface, and possibly the migration of gas or oil or water in the subsurface across geologic time. The more pipelines come in contact faults the greater the risk; the effect could be worse for natural gas lines that have more conductive water in the gas. Figure 2 shows how hot zones can be identified in an example near Houston.



Recent studies have shown GIC can alter the flow of electricity in a power system so much blackouts result[5]. GIC has also been referred to as “space weather,” but in reality it is the charged particles from the sun entering the atmosphere and streaming as the Earth’s electric field. A study in Finland concluded GIC in technical systems, such as pipelines, are the ground end of the complicated chain and that the impact of GIC greatly depends on the pipeline configuration[5].

DML has learned GIC are more active along fault lines just like Earth currents and lightning. In the past, it’s likely these hazards have not been considered by pipeline companies when planning or laying lines. That will change in the future. Accounting for and protecting against GIC could easily extend the lifetime of a line by 25%.

There is no question that technological advances will alter the future for energy services companies and lightning has become a new data type that is taking the industry by storm. Recent advances in the ability to measure and analyze lightning are making all of this possible. While this technology is still in its early stages, all indications are that it will be beneficial to many companies that may have never considered it before and could literally save billions of dollars. One thing is sure; we will never look at lightning the same way again.

Jim Siebert is chief meteorologist for Houston Fox 26 News and the co-founder of Dynamic Measurement.

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