Lightning Analysis for Mapping Faults and Identifying Exploration Sweetspots

AAPG Pacific Coast & Rocky Mountain Section Meeting in Las Vegas, NV

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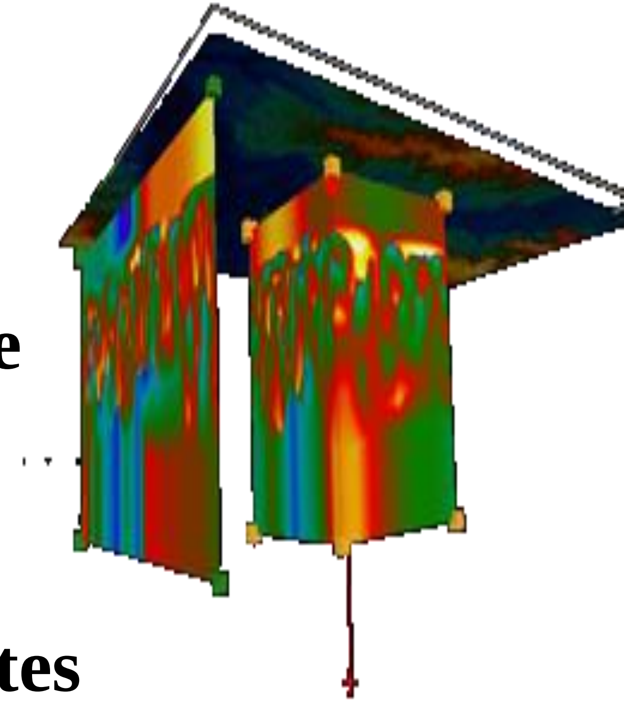
Dynamic Measurement LLC
04 October 2016

Milam County Texas apparent-resistivity Volume

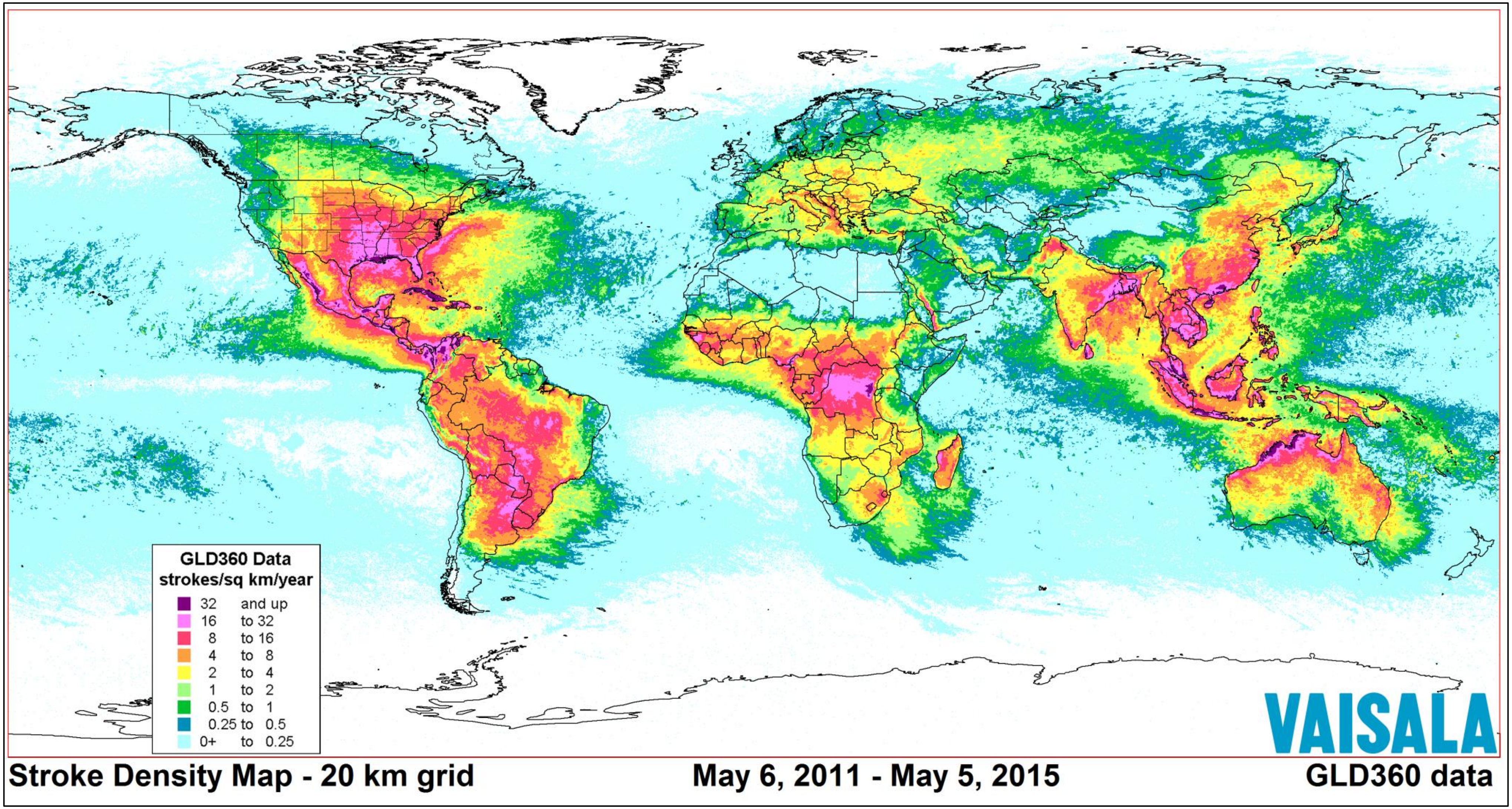


Presentation Outline

1. Lightning Occurs Everywhere
2. Lightning Database Analytics
3. Lightning Analysis & Attributes
4. Rock Property & Attribute Maps & Volumes
5. Arizona, Louisiana, Michigan, & Texas Examples

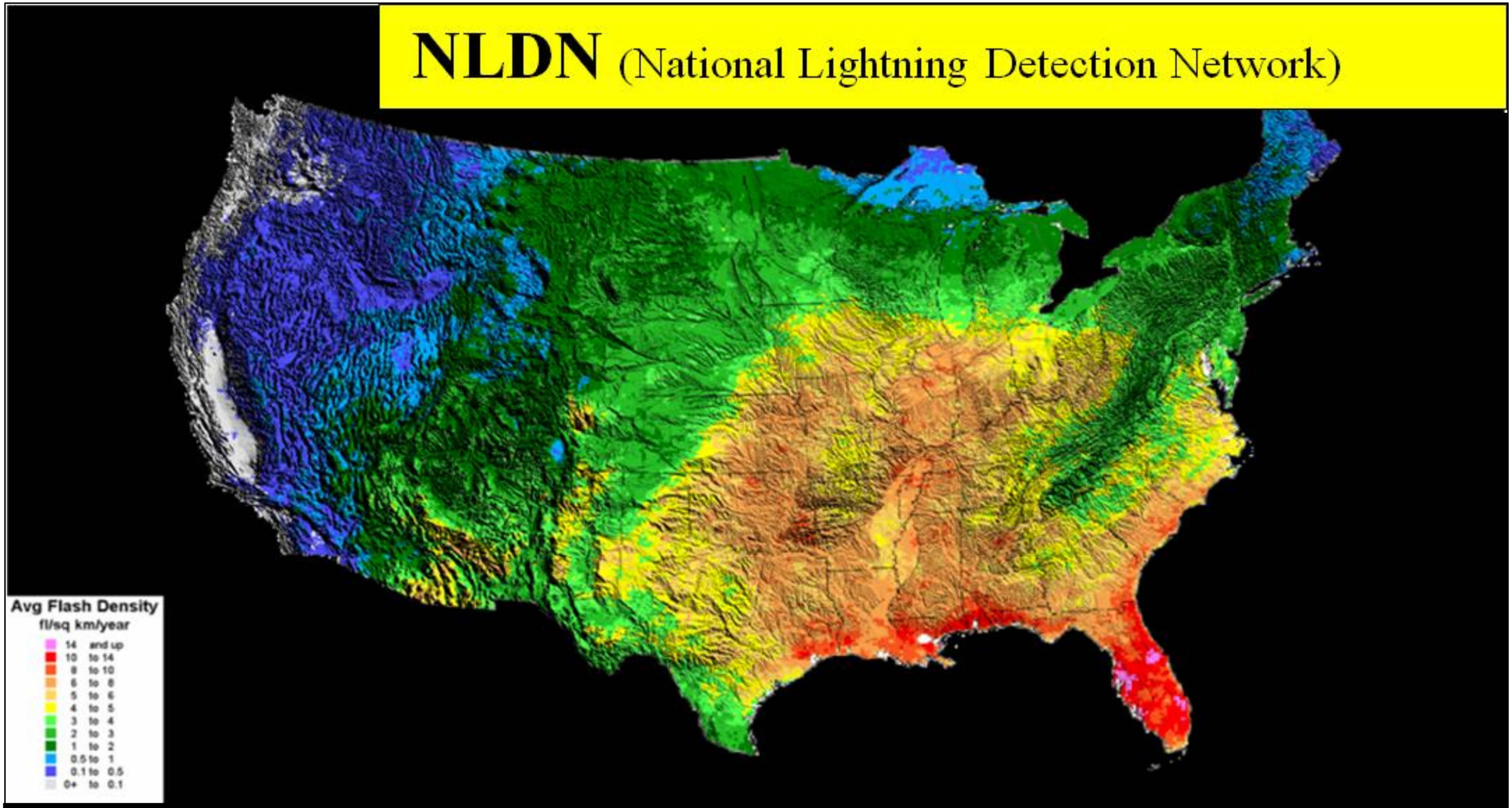
1. Lightning Occurs Everywhere

5+ years of data in GLD-360 database



The U.S. has the most complete database

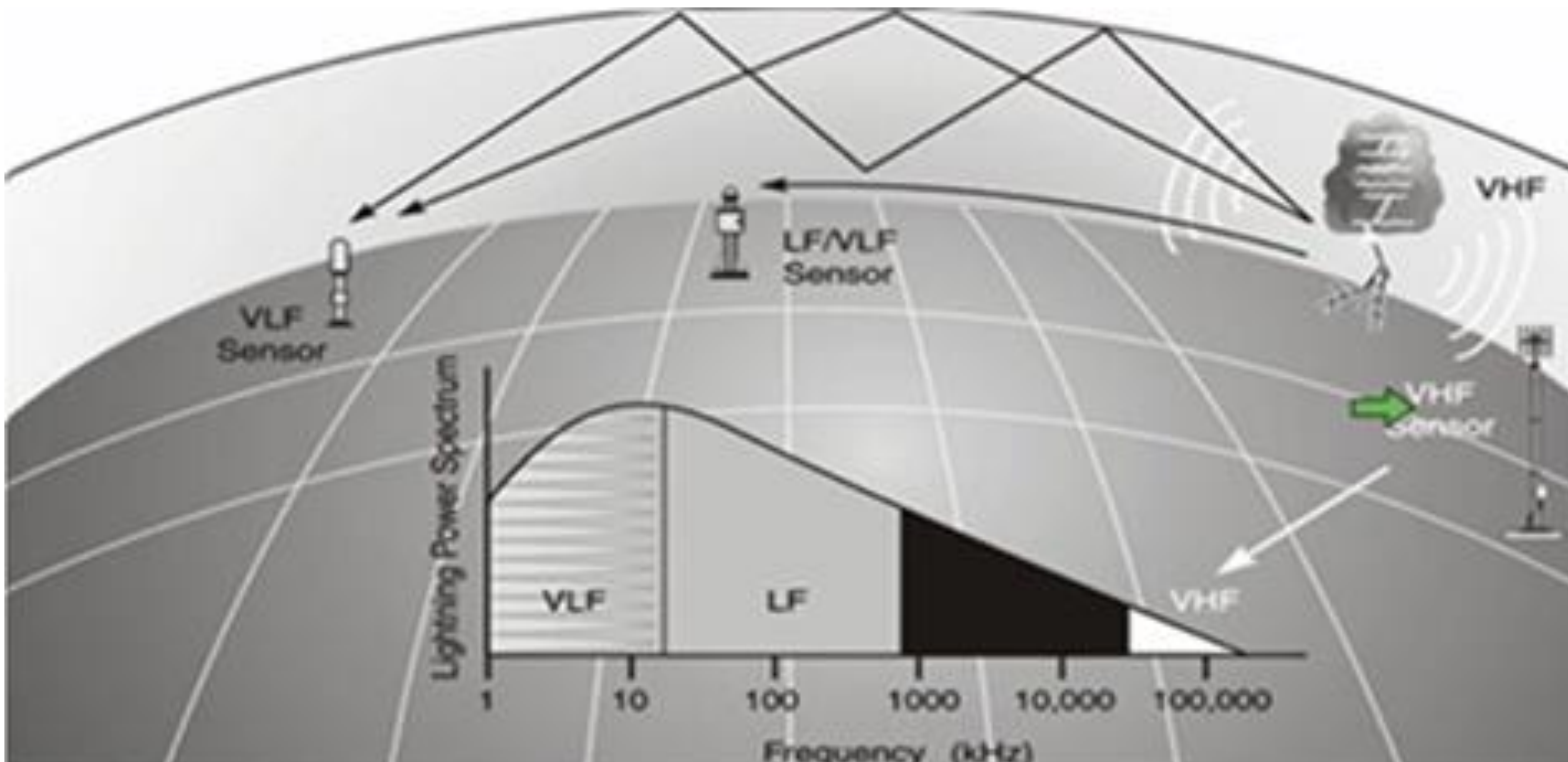
18+ Years of Data in the NLDN Data Base



Originally Collected for Insurance, Meteorology, and Safety Reasons

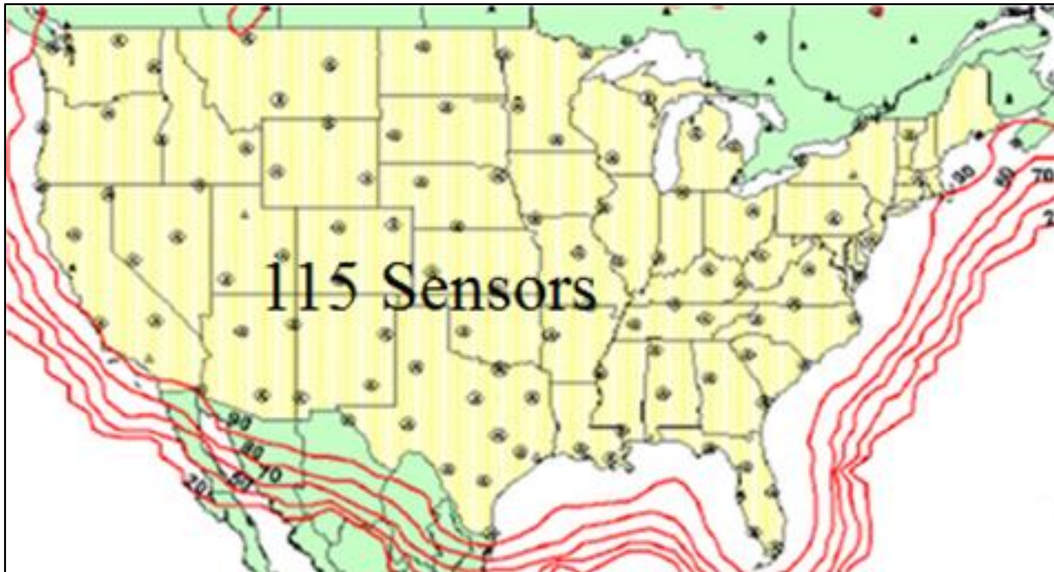
Sensors Measure Direction to Strike & Lightning Attributes

Strike Triangulated & Measurements Reconciled



Vaisala: Martin Murphy
2016 Webinar used with permission

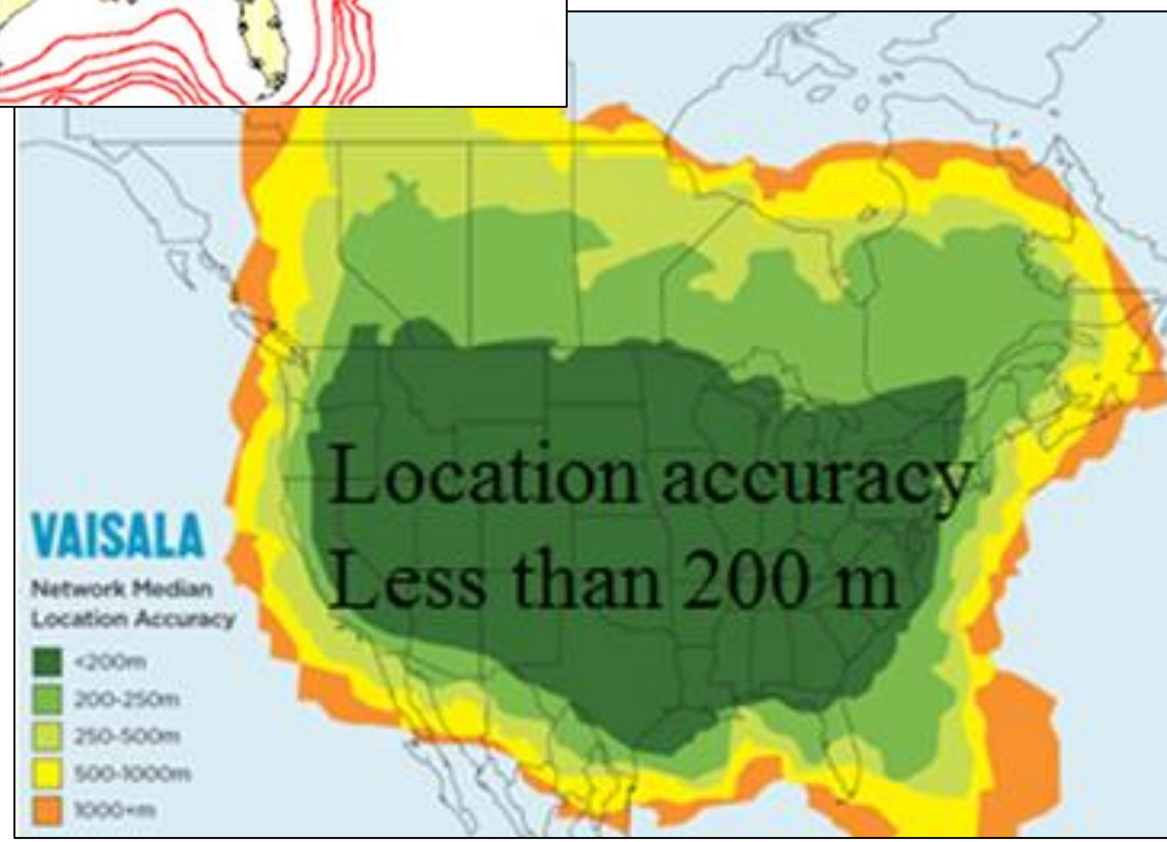
Vaisala's NLDN Lightning Detection Network



In Texas 12-24 sensors record each lightning strike

Location Accuracy:
150-600 feet

Lineament Accuracy:
10-100 feet



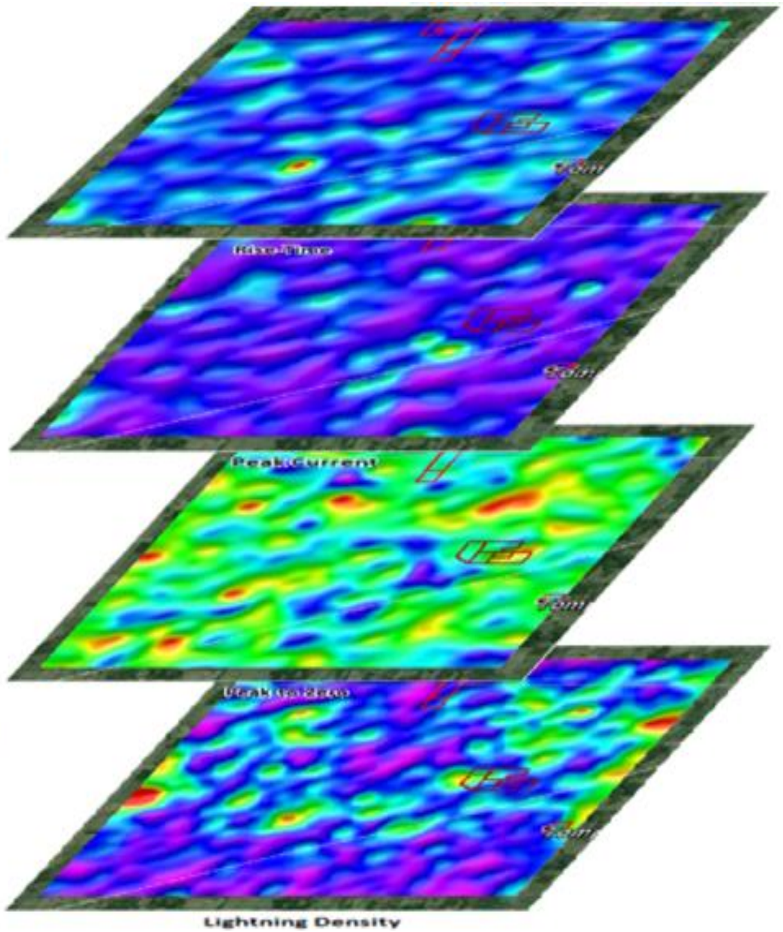
From 2016 Vaisala Webinar: Martin Murphy, used with permission

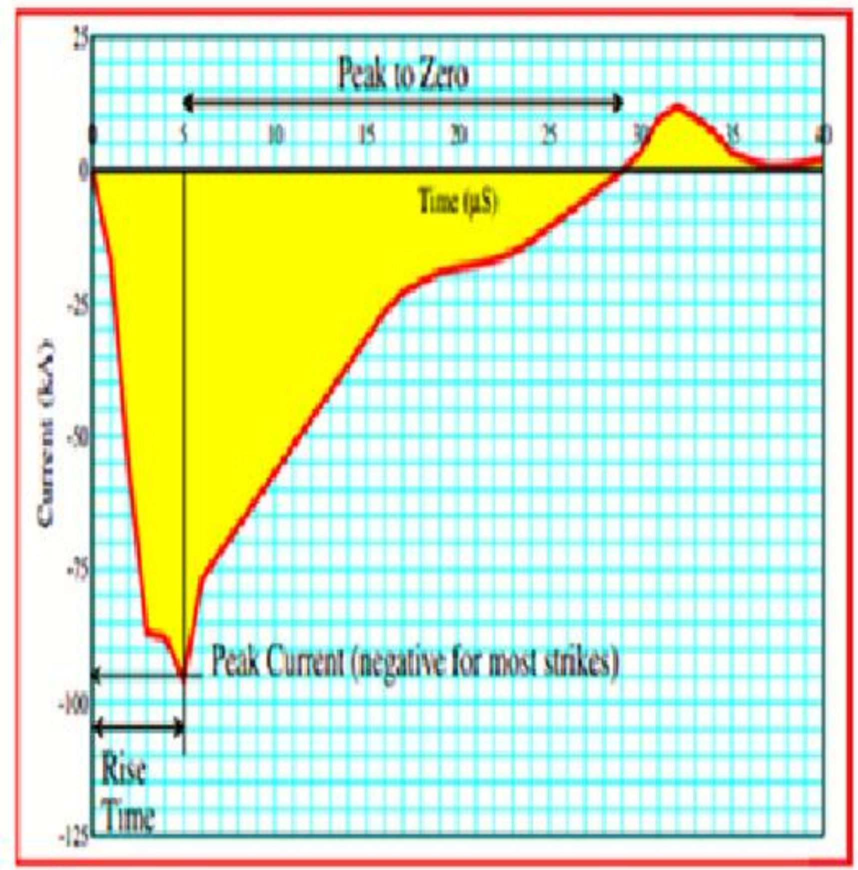
2. Lightning Database Analytics

- Typical projects have millions of lightning strikes.
- To date all projects have tied subsurface control.
- Attributes are measured or calculated for lightning strike locations, then contoured or gridded.
- Lightning strike density and attribute values cluster, and these clusters are somewhat consistent over time.
- Lineaments, like fault scarps, have been mapped with 30 foot horizontal location accuracy.

Lightning Measurements

- Location
- Time and Duratic
- Rise Time
- Peak Current
- Polarity
- Peak-to-Zero
- Density
- Major/Minor Axe
- Chi-Squared

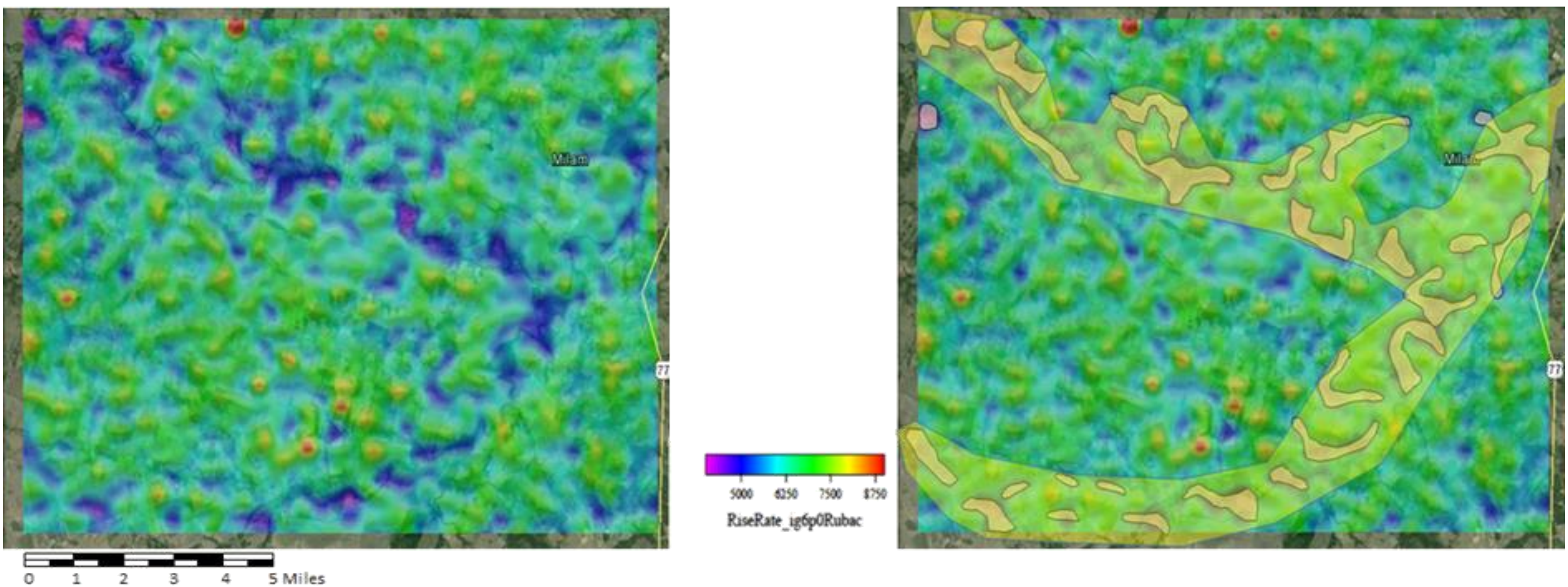




- Other attributes calculated from these measurements.
- The time of the lightning strike is correlated with solar and lunar tides.
- Measurements separated by time.

3. Lightning Analysis & Attributes

1. **Analysis area selected.**
2. **Patented and Patent-Pending Processes produce maps and volumes of derived rock properties and lightning attributes.**
3. **Existing geology and geophysics integrated with new data.**

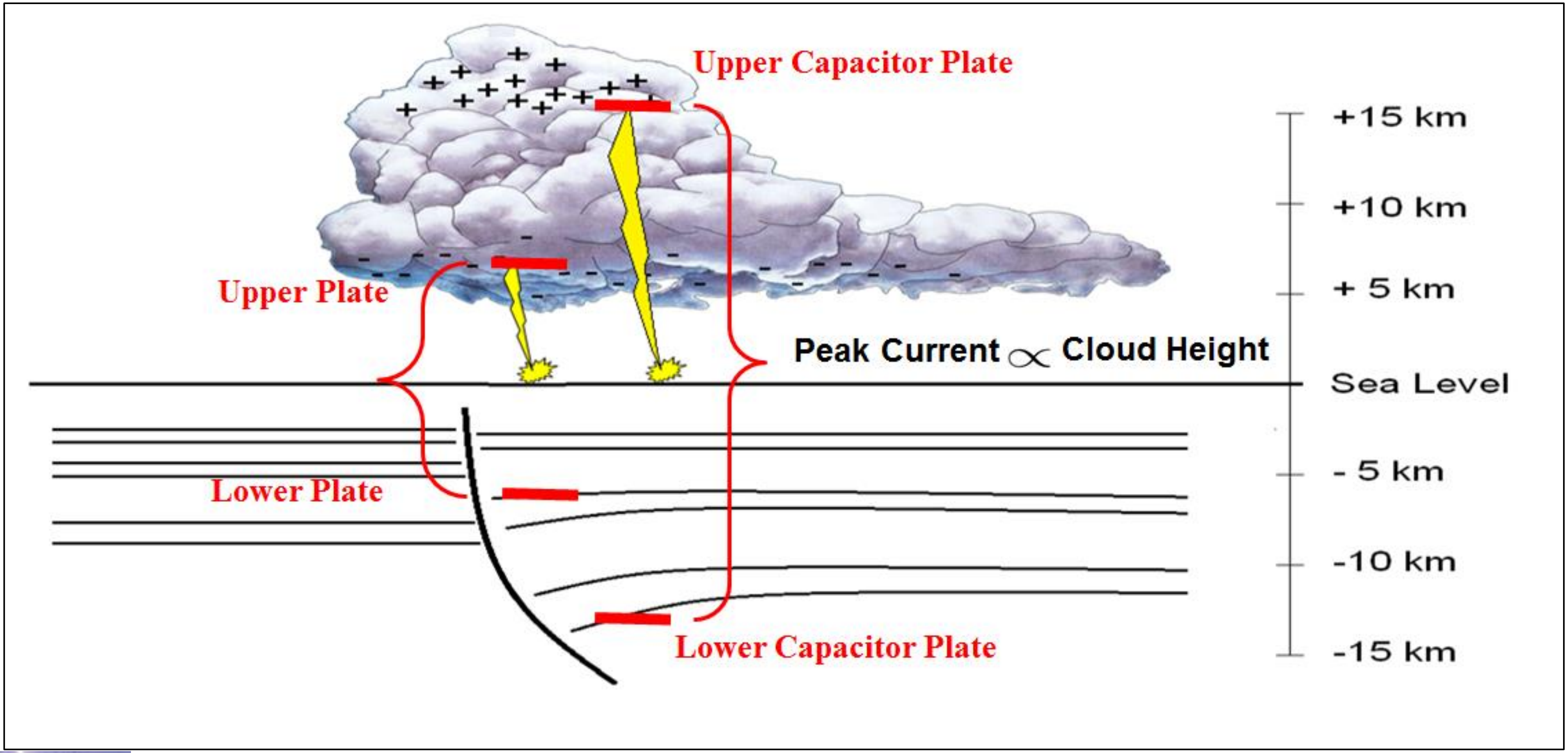


Lightning Attribute: Rate of Rise-Time – Milam County, Texas

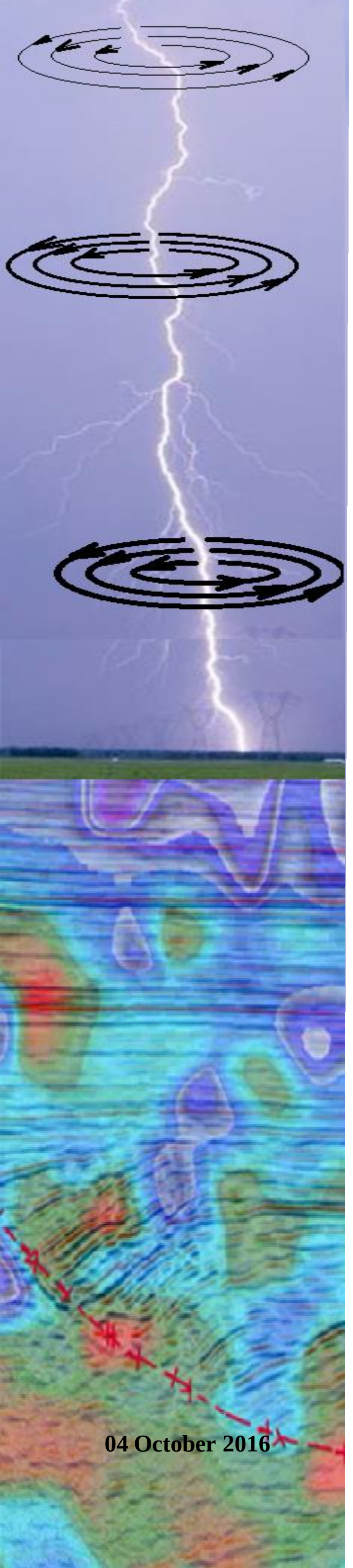
4. Rock Property & Attribute Maps & Volumes

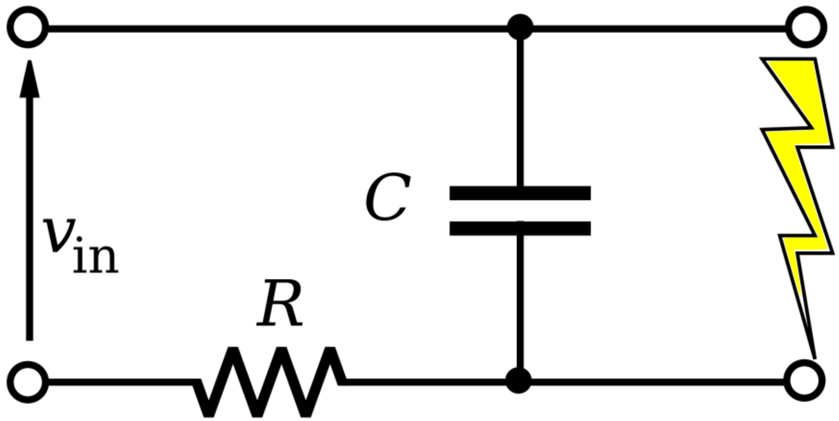
Key Assumptions:

1. Lightning occurs when there is sufficient charge to bridge the capacitor.
2. Lightning is affected by geology to a depth proportional to cloud height, as derived from Peak Current



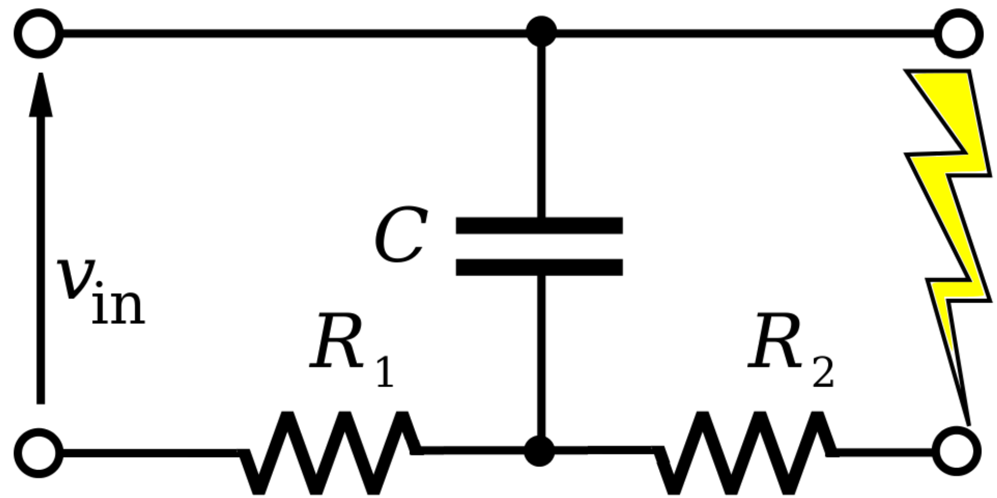
Relaxation Oscillator Physics and Lightning (a giant neon tube)



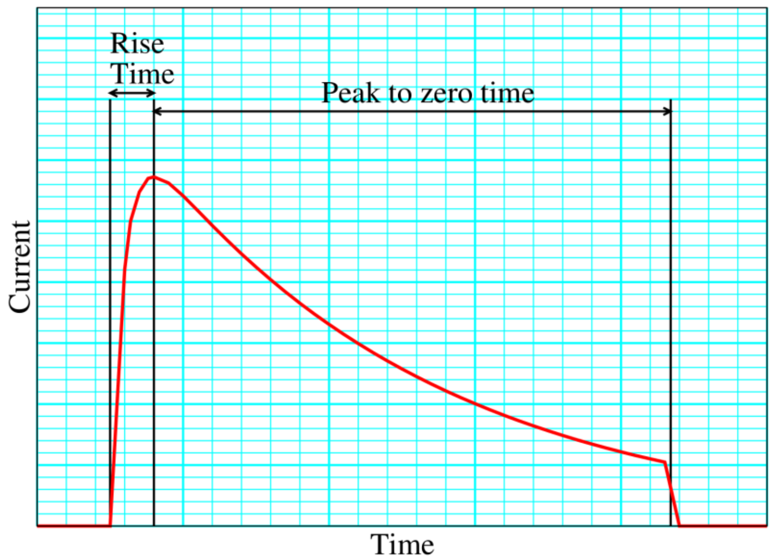


- The atmospheric capacitor is like a relaxation oscillator
- Just an additional resistance (R_2) limiting the current

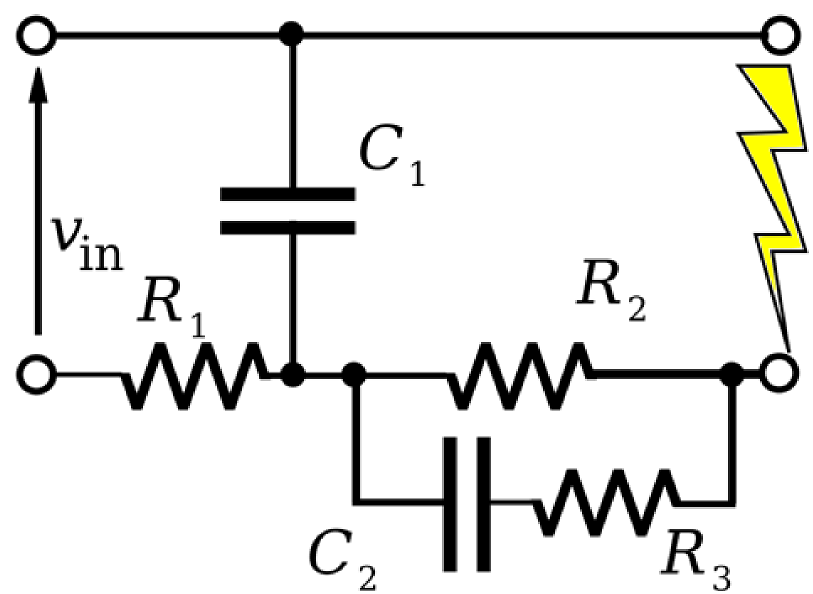
- R_2 is the resistance between the lightning strike point and the bottom plate of the capacitor



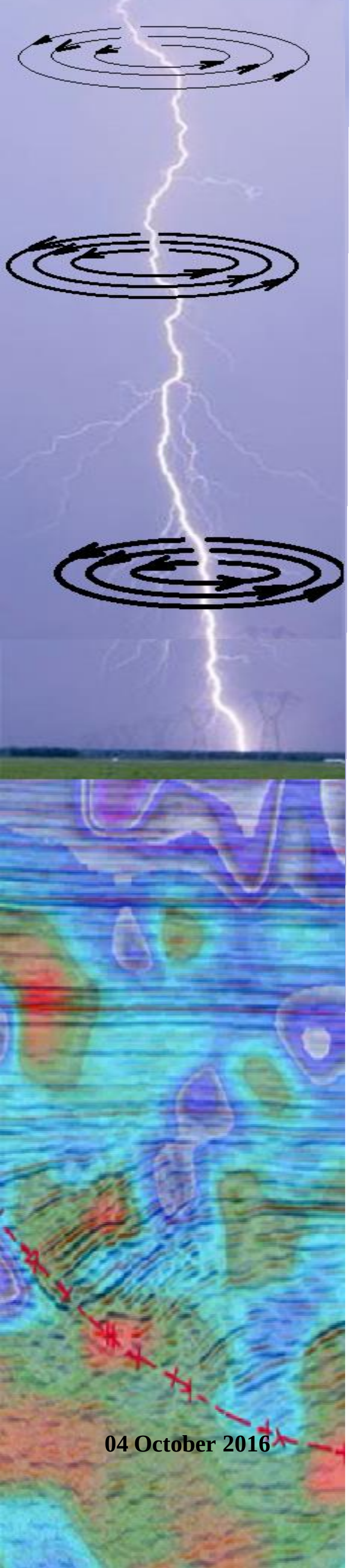
Lightning and the Induced Polarization Effect



- Lightning does not have a square waveform
- But it does have a very steep onset
- Variations in the onset as measured (rise-time) show the IP Effect



- By treating this steep onset as charging a capacitor (C2) through a resistor (R3), an apparent capacitance can be calculated.
- From the apparent capacitance a value for apparent permittivity can be calculated



Skin Depth is NOT the Controlling Factor

Charging Telluric Currents:

Lightning strikes are passive energy pulses, and contain all frequencies.

The skin effect of the high frequency information recorded in the ~50 microsecond total-wavelet time does not control the depth electrical energy interacts with telluric currents.

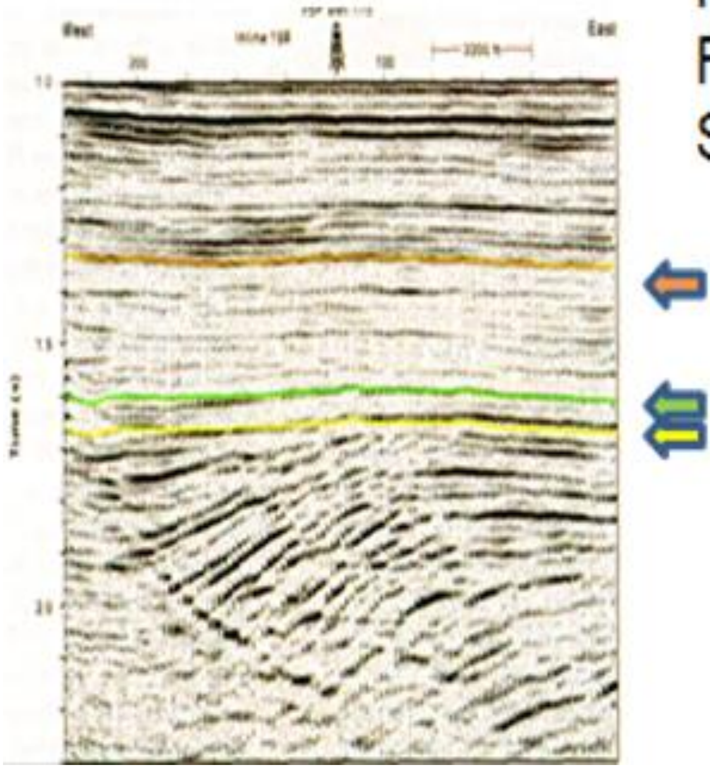
Interval of Interest:

Traditional lightning does not occur in clouds less than ~1,500 feet in height, nor for clouds higher than ~30,000 feet.
The depth interval where lightning volumes are useful is typically from 1,500-30,000 feet.

Data Distribution:

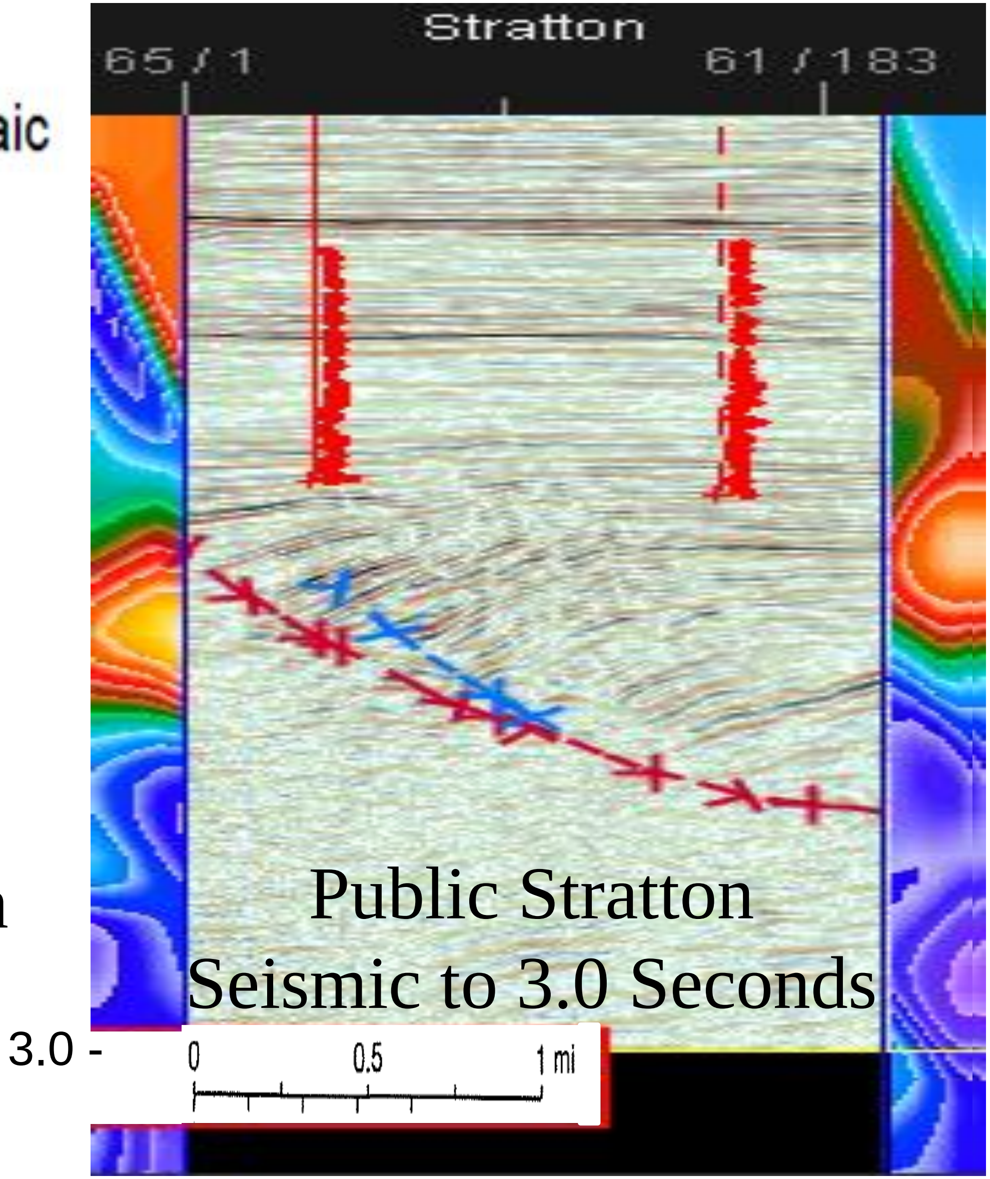
Volumes converted to SEG-Y files for workstations.
Volumes interpolated to match aeromagnetic or 3-D seismic surveys.
Resulting rock property or lightning attribute volumes are overlaid on the seismic or other geologic cross-sections like a velocity volume.

Stratton Seismic Sections, South Texas



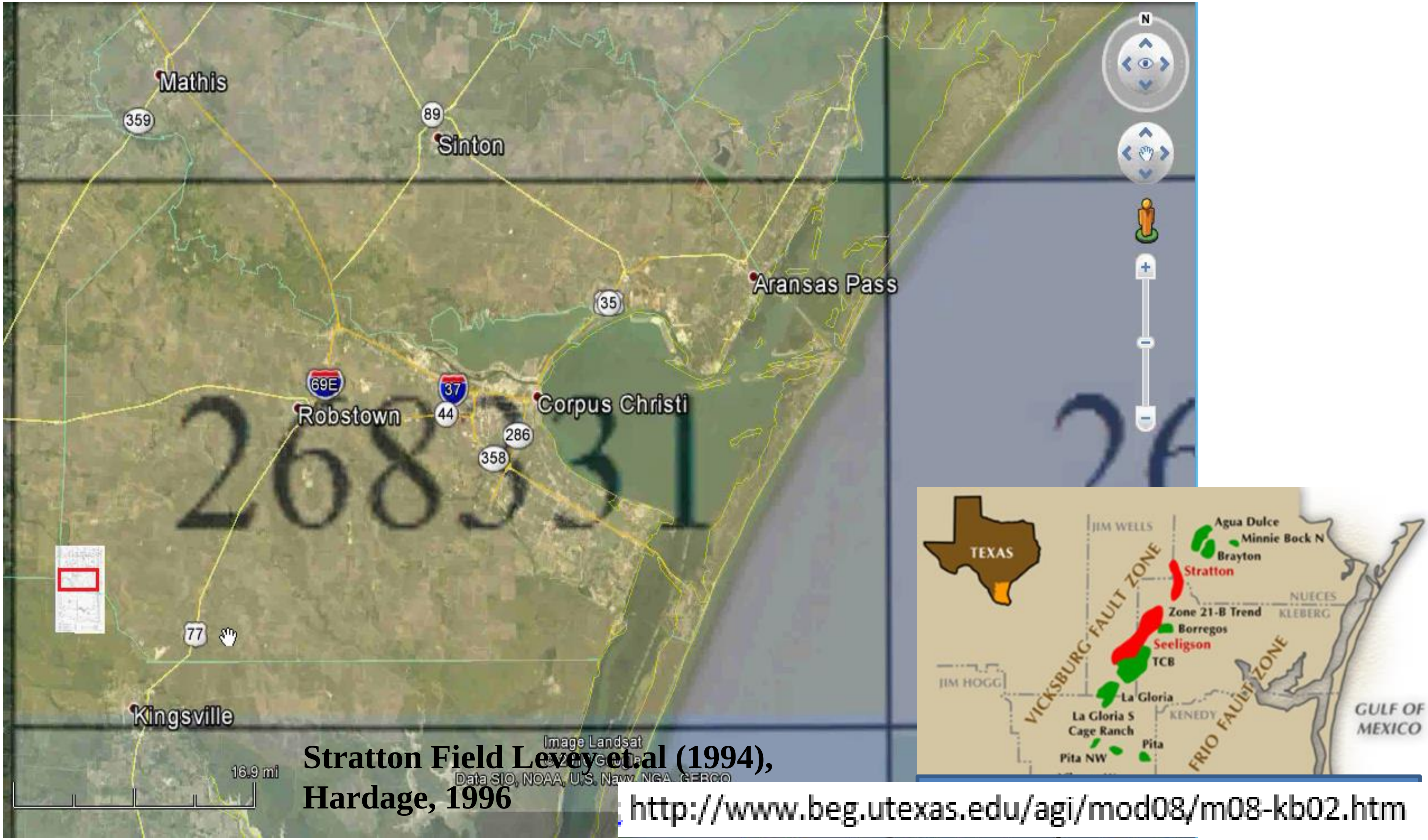
Frio Horizons
Fluvial – Deltaic
Sands

Published BEG Stratton
Data to 2.3 seconds
(Hardage, 1986)



Public Stratton
Seismic to 3.0 Seconds

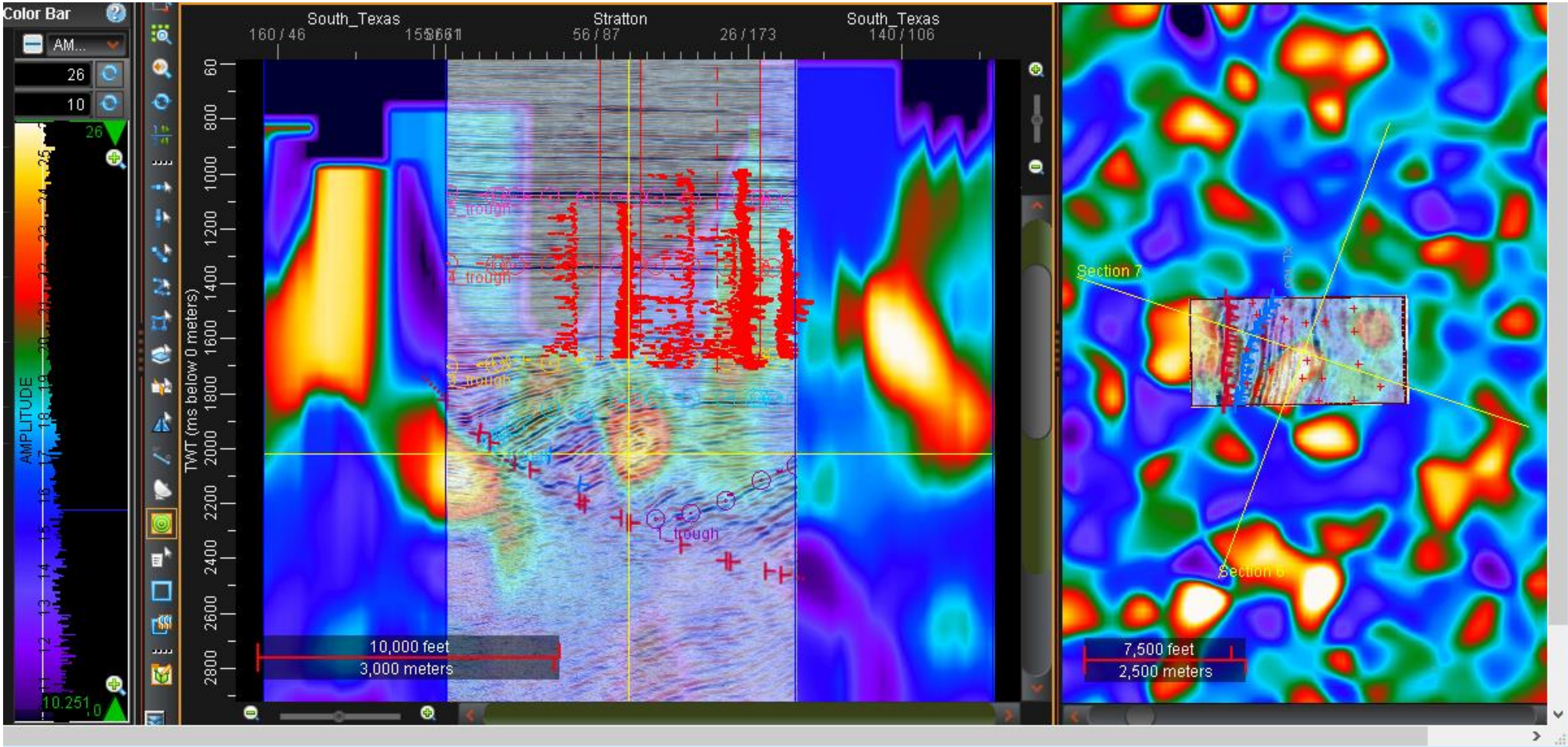
Study Area around Corpus Christi



Stratton Field Levey et.al (1994), Hardage, 1996

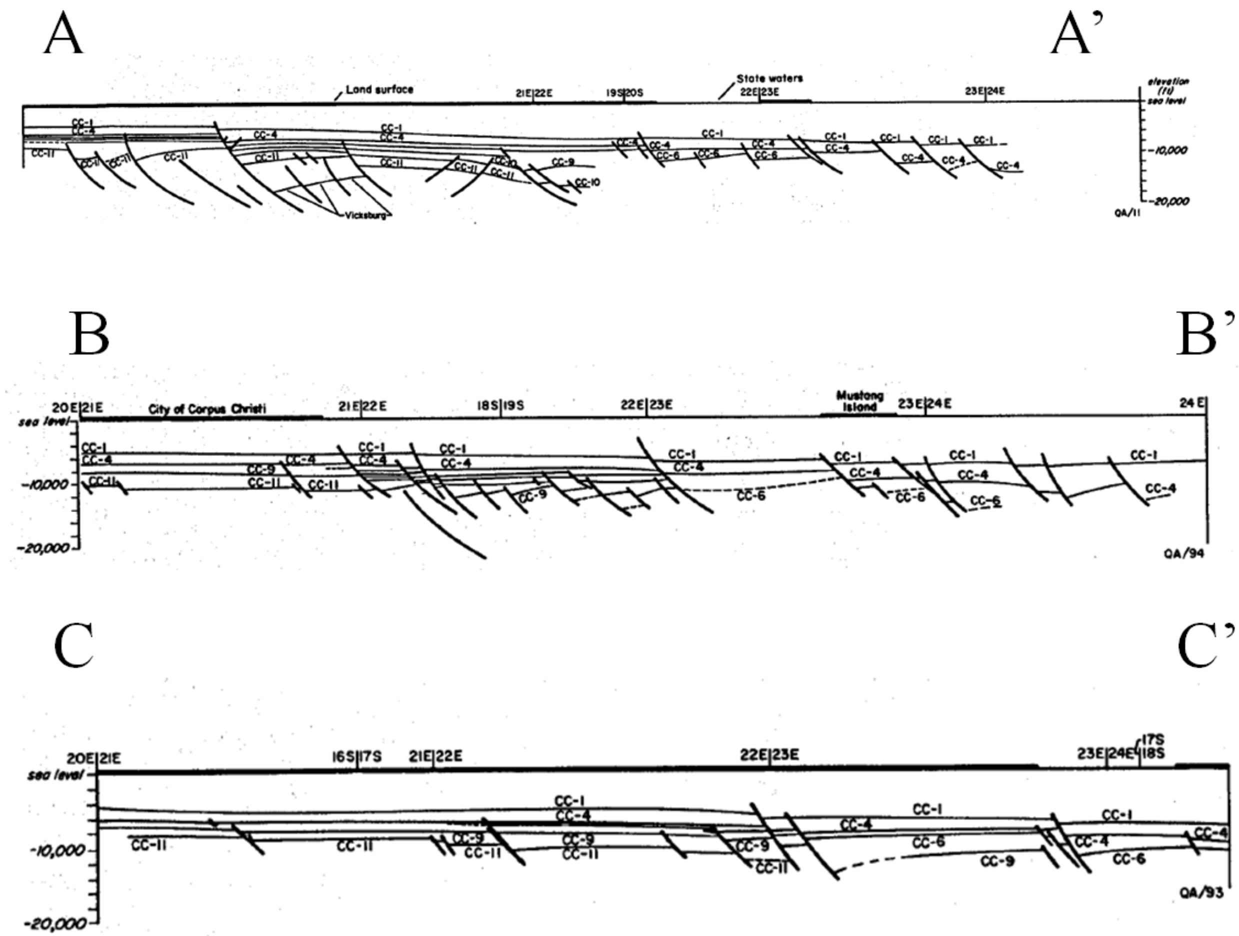
http://www.beg.utexas.edu/agi/mod08/m08-kb02.htm

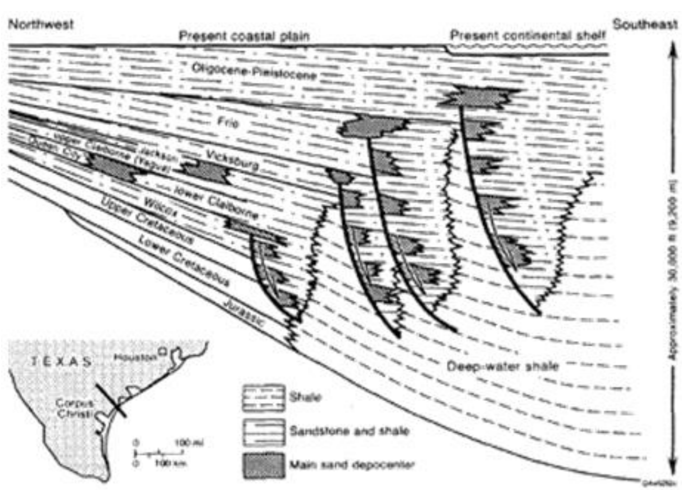
Stratton Apparent-Resistivity Sections



Working on calibrating depth and calculated vs. measured resistivity

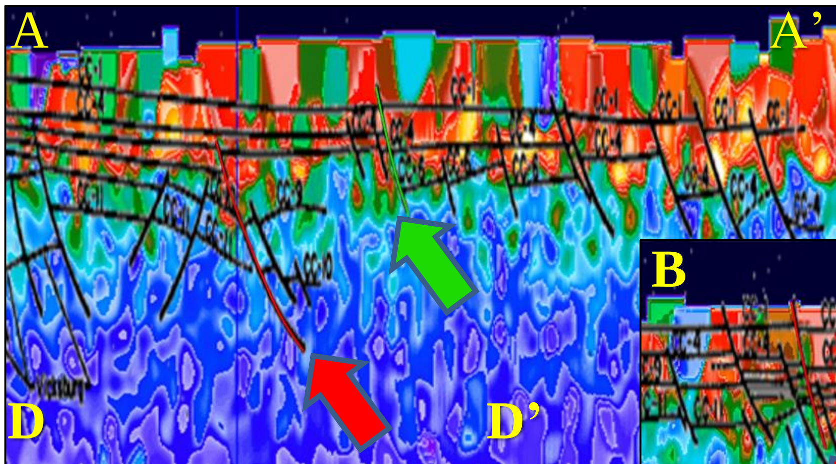
Study Area - Geology and Structure Corpus Christi from Ewing (1986)

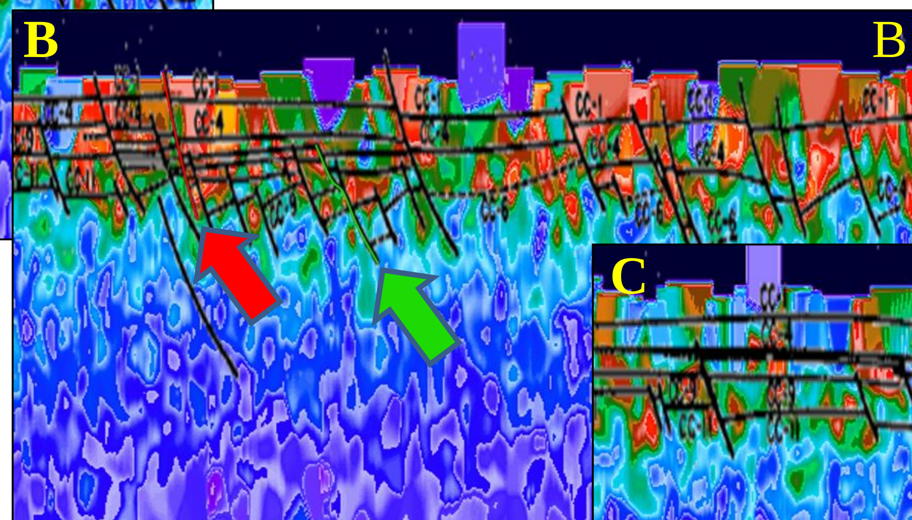


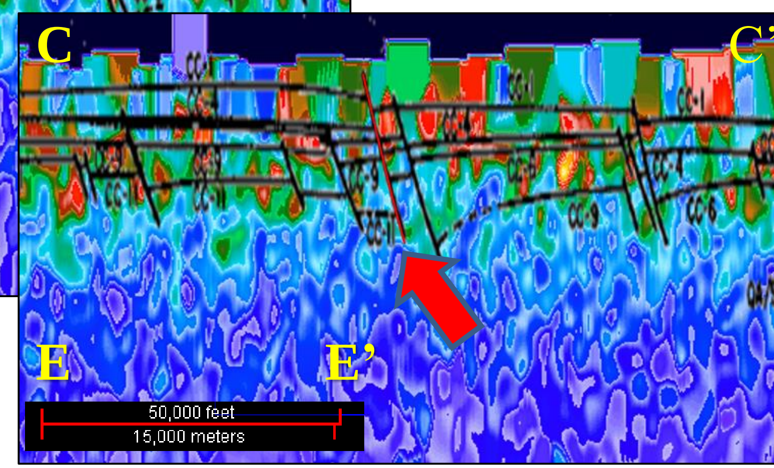


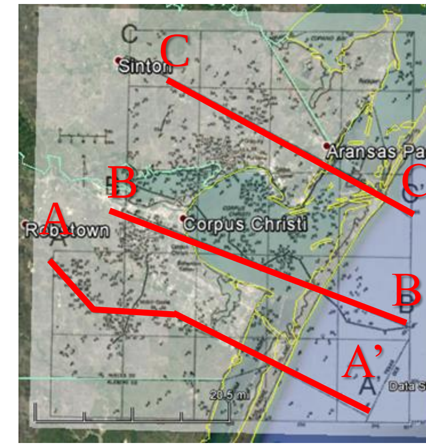
From Levey, et al,1994
Bebout and others,1982

2016 Lightning-Derived Resistivity Cross-Sections Match Geology on 1986 Ewing Interpretation Overlay





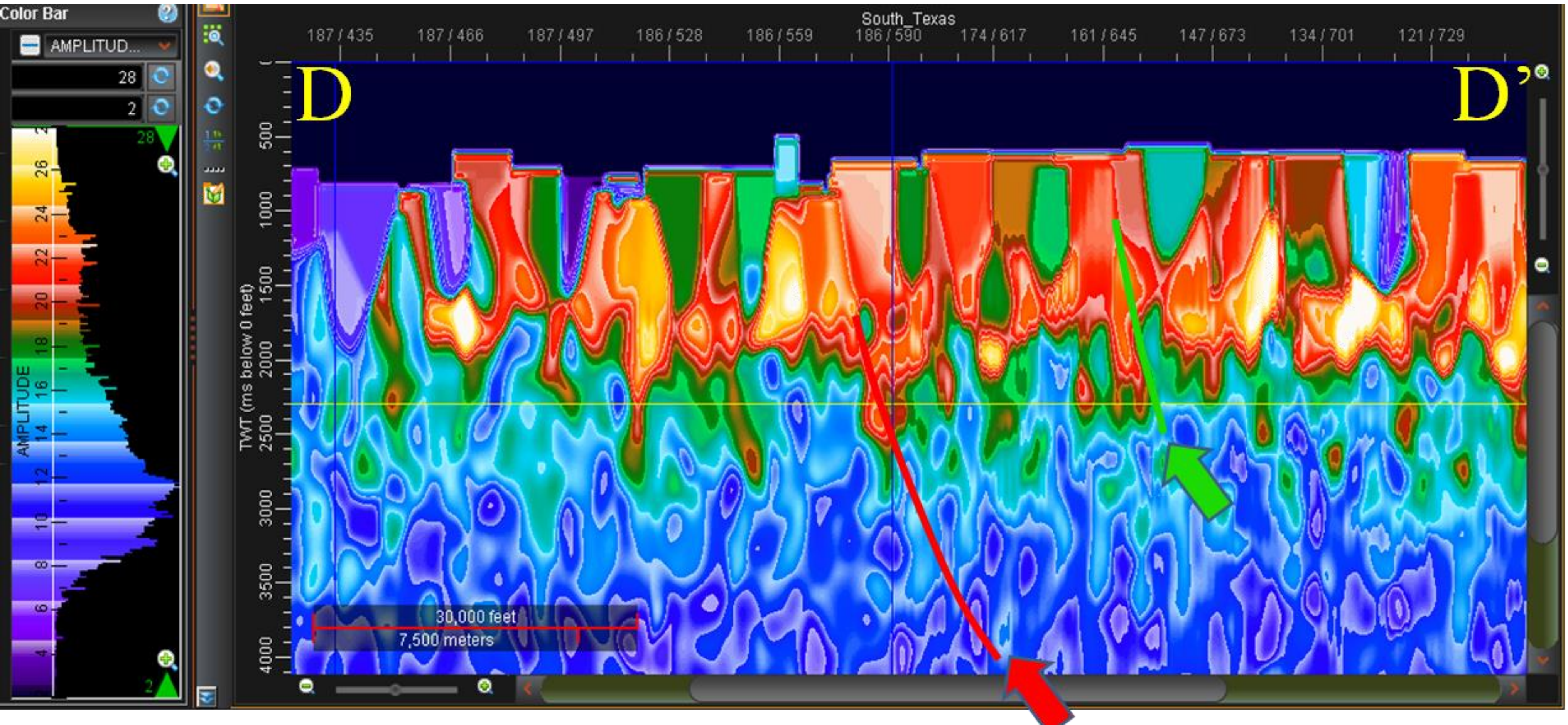




Red and Green Arrows show faults correlated between Ewing cross-sections using Ewing fault plane maps

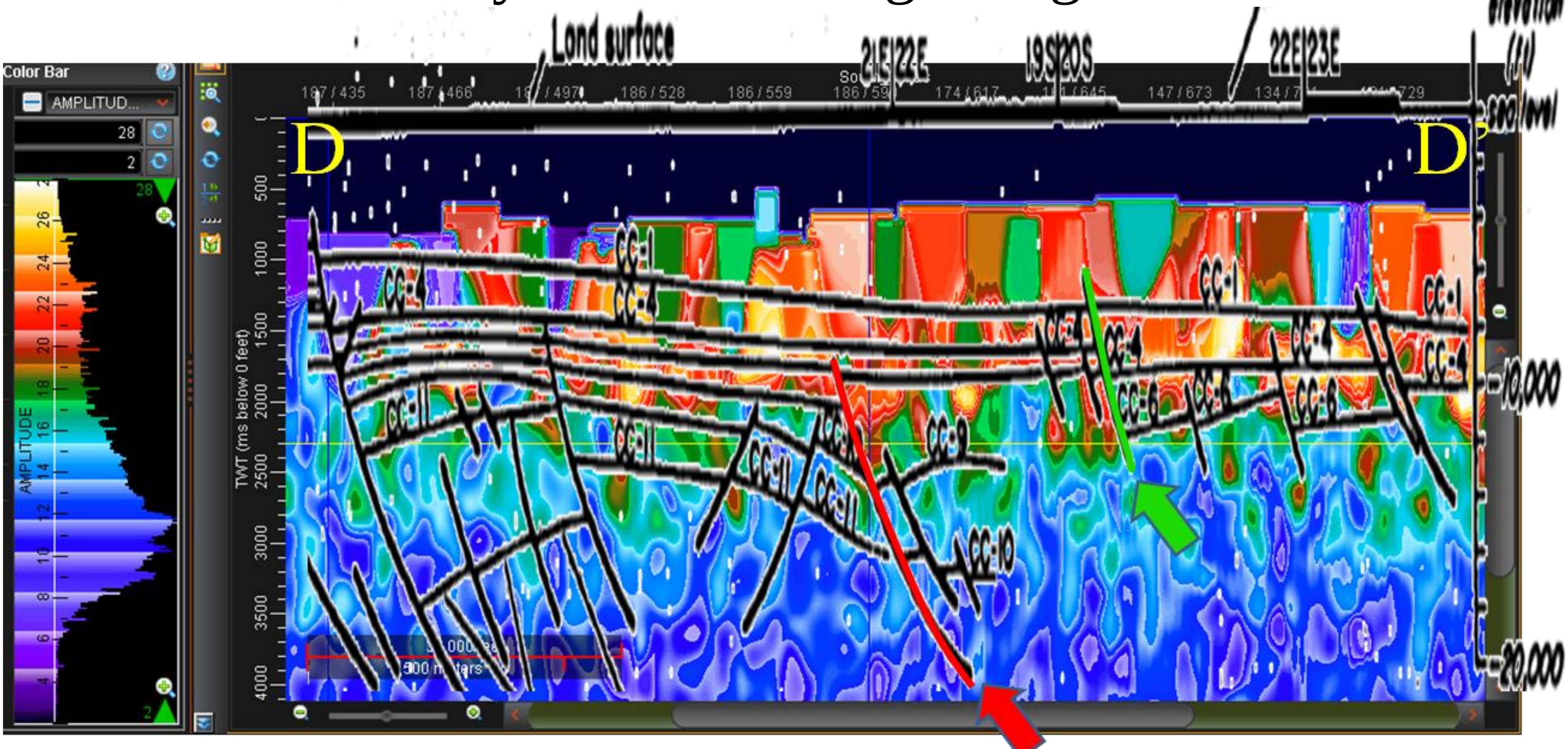
(Fault Overlays Ewing 1986)

D-D' Close-Up on Graben on A-A' without overlay



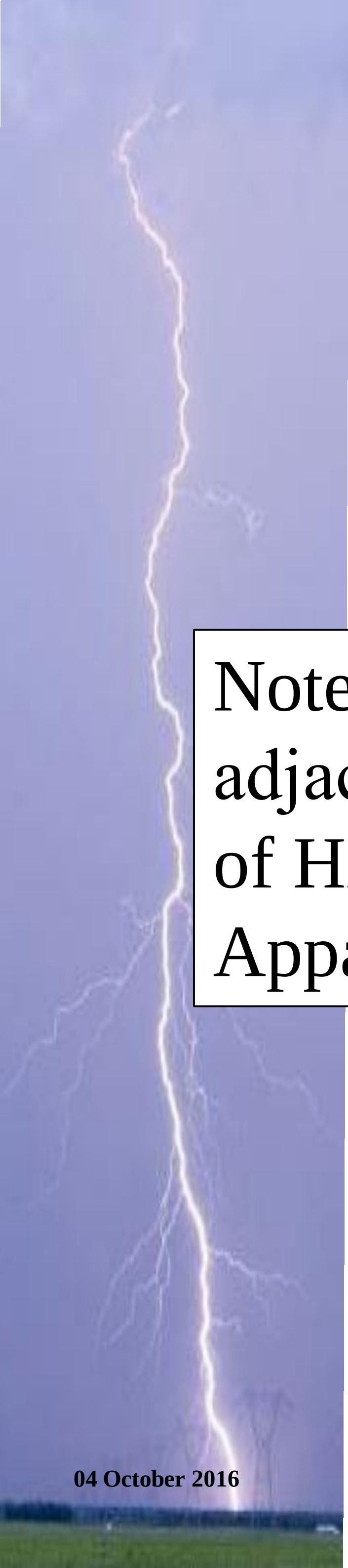
Red and Green Faults were major faults on Ewing's maps. Note high apparent-resistivity events (bright) appear to have plumes above these faults.

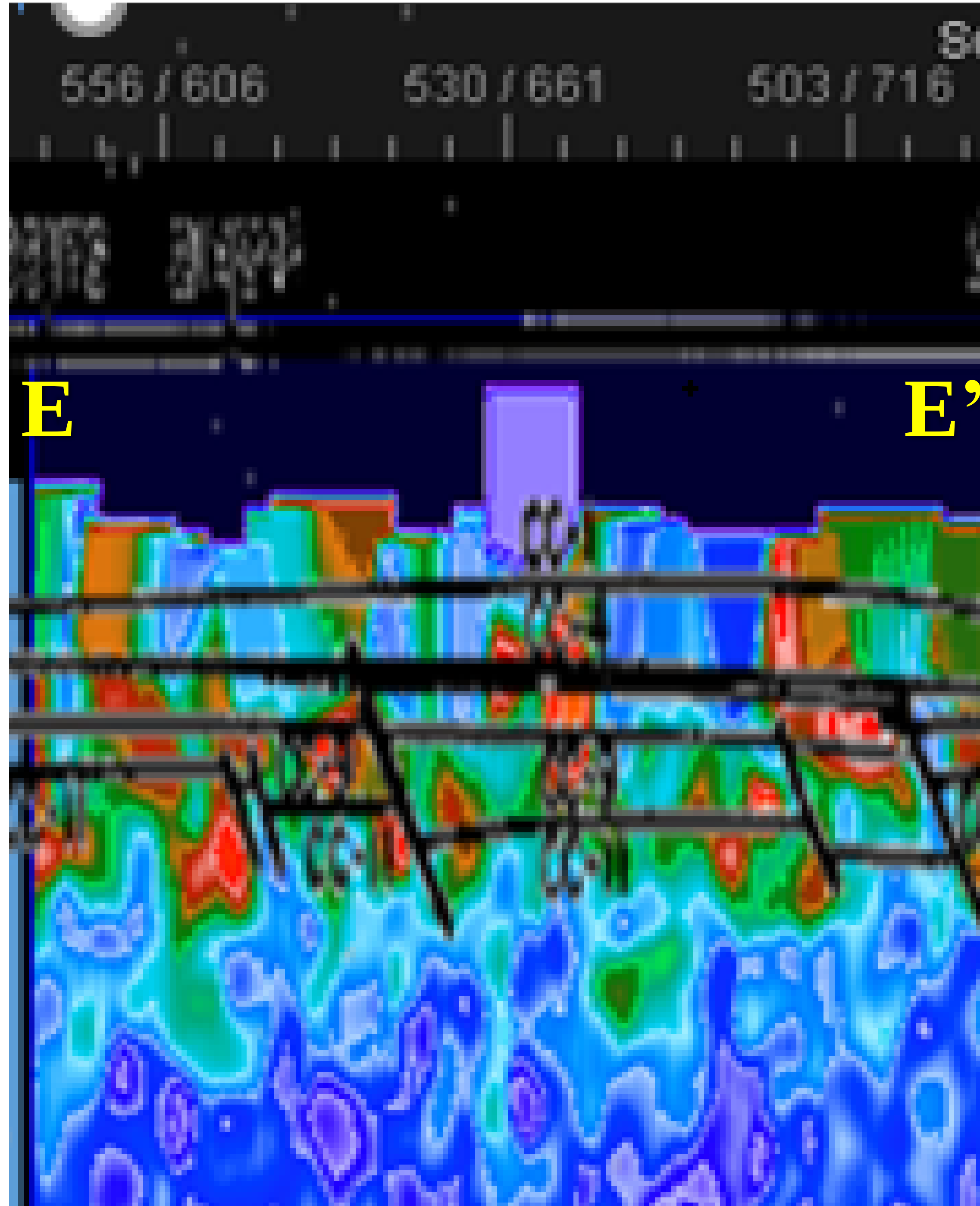
D-D' Close-Up on Graben to the west
Interpretation 1986 by Tom Ewing, Apparent Resistivity 2016 from Lightning Databases



Note: interpretation by Tom Ewing in 1986. The resistivity section calculated from lightning in 2016. Co-located sections show breaks where faults were interpreted. There are resistivity plumes tied to faults.

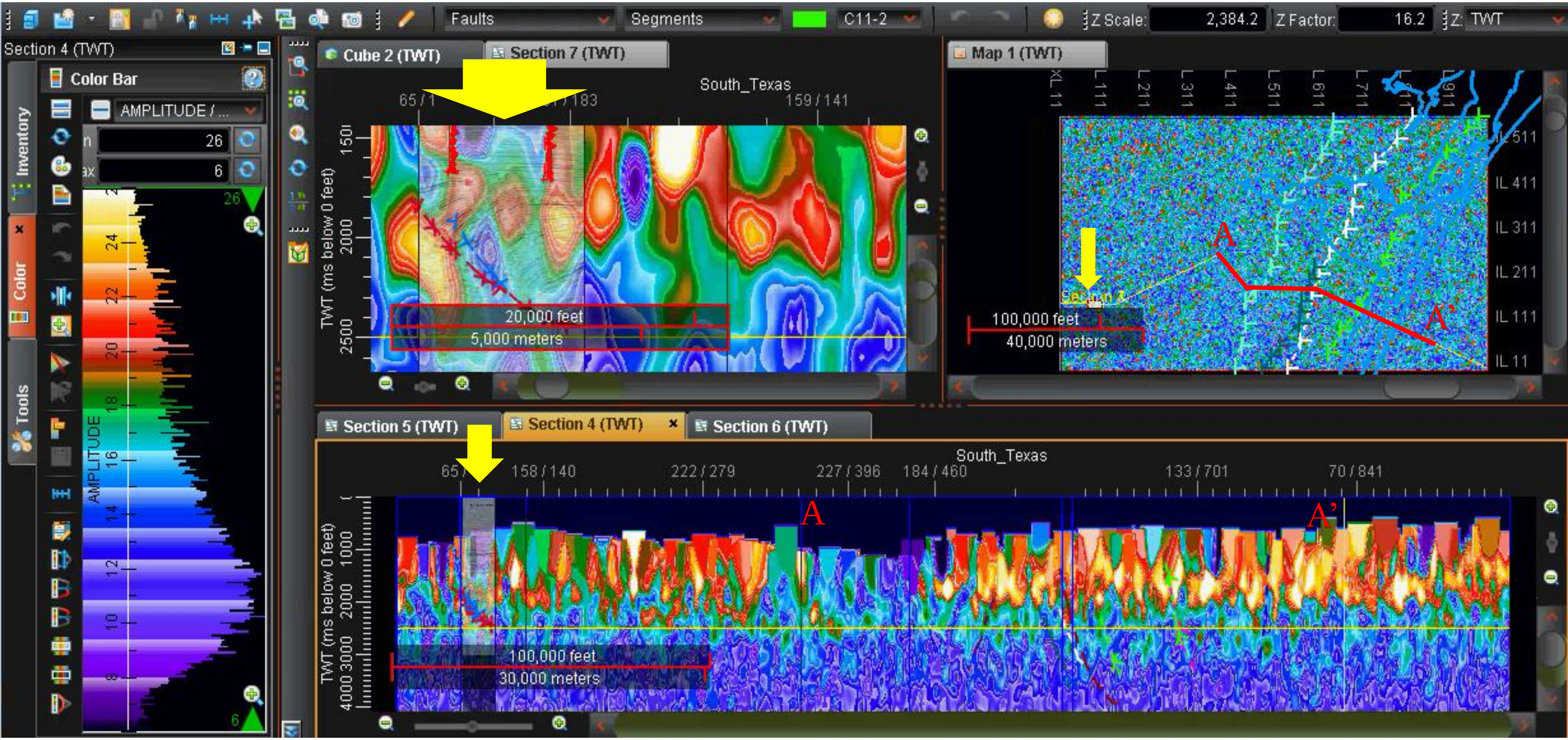
E-E’ on the Northwest End of Ewing’s C-C’





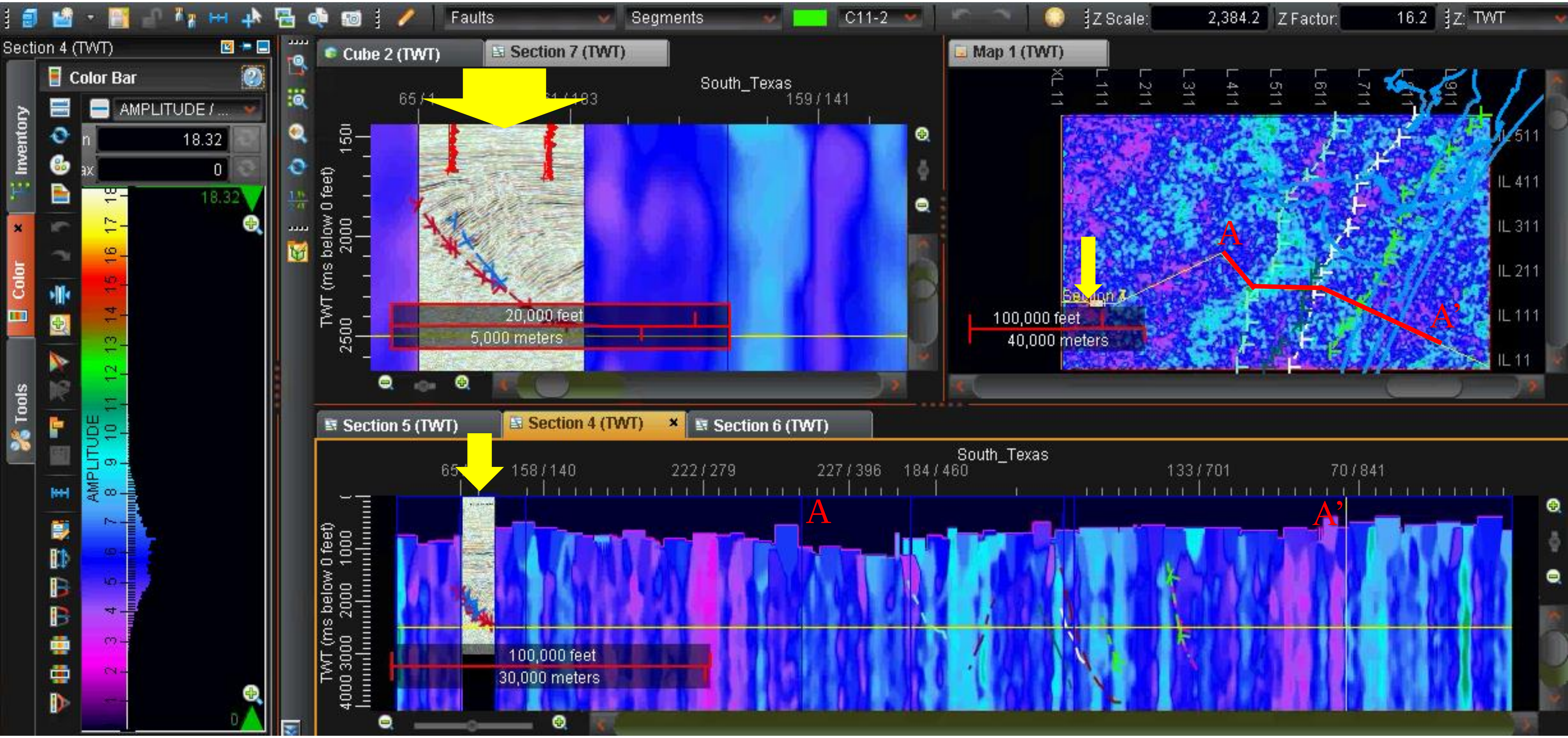
Note offsets in adjacent “Packages” of Higher Values of Apparent Resistivity

Apparent-Resistivity Extension of Ewing (1986) A-A' through Stratton seismic data



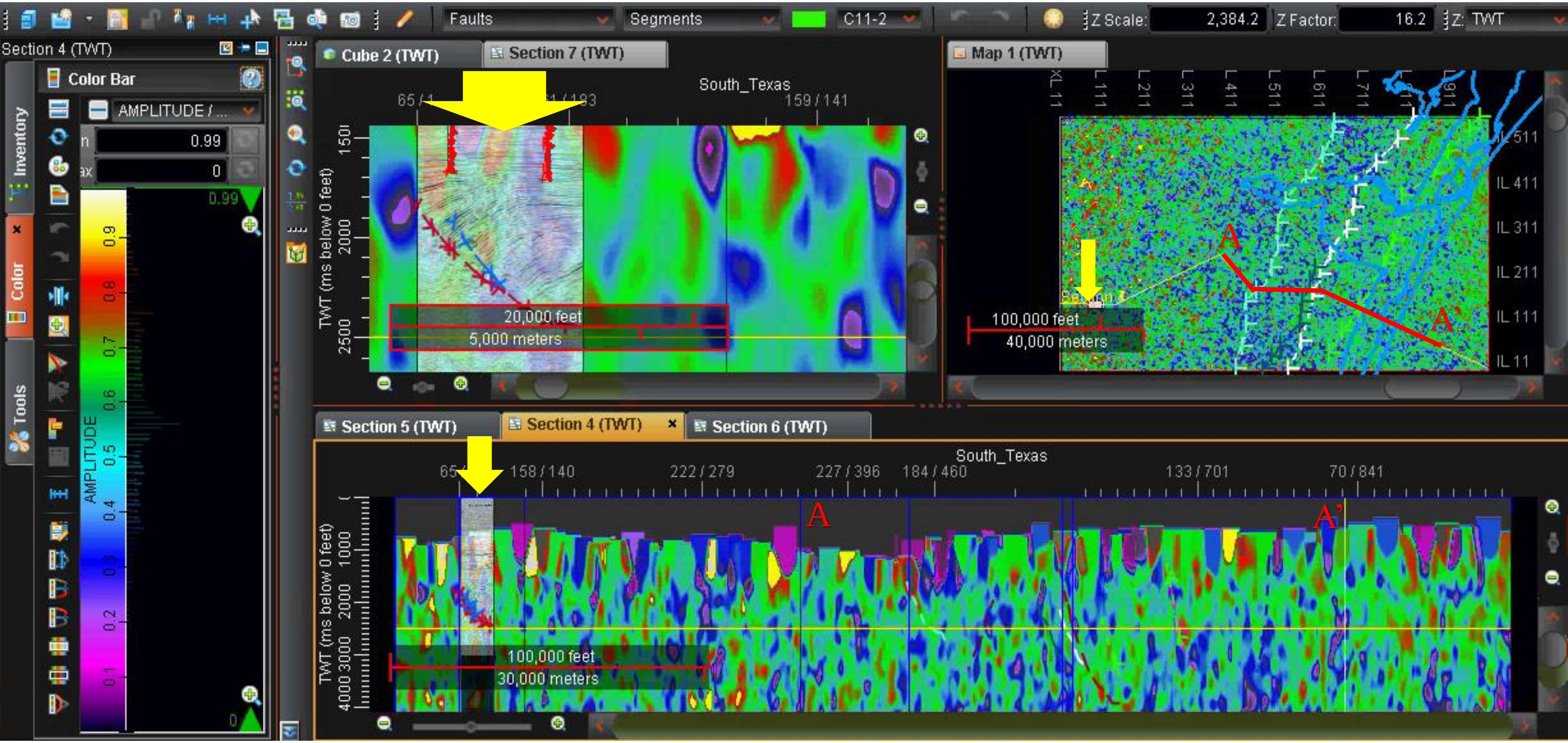
(ohm-meters)

1 of 18 Lightning Attributes - Density



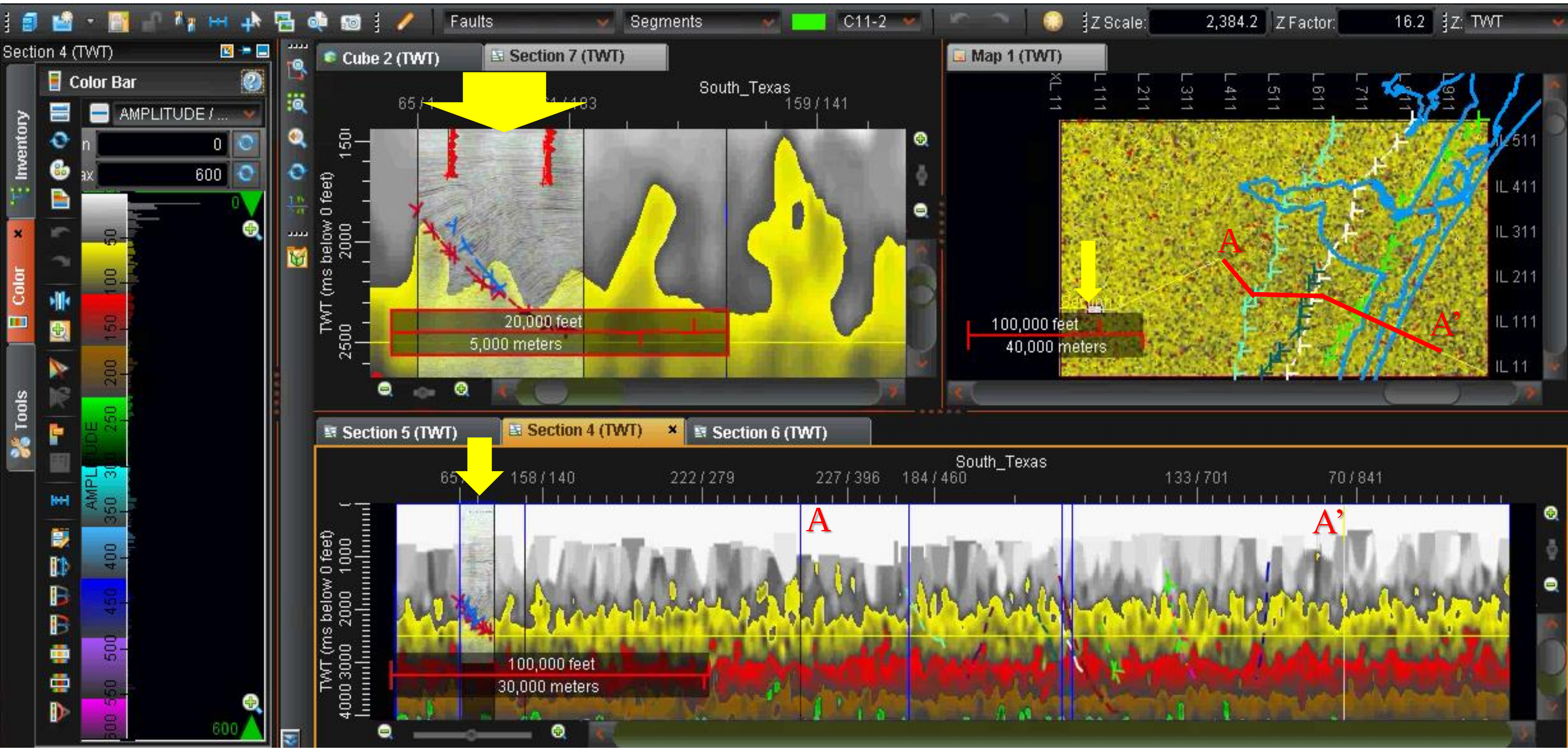
(Strikes per square kilometer)

2 of 18 Lightning Attributes - Day of Year



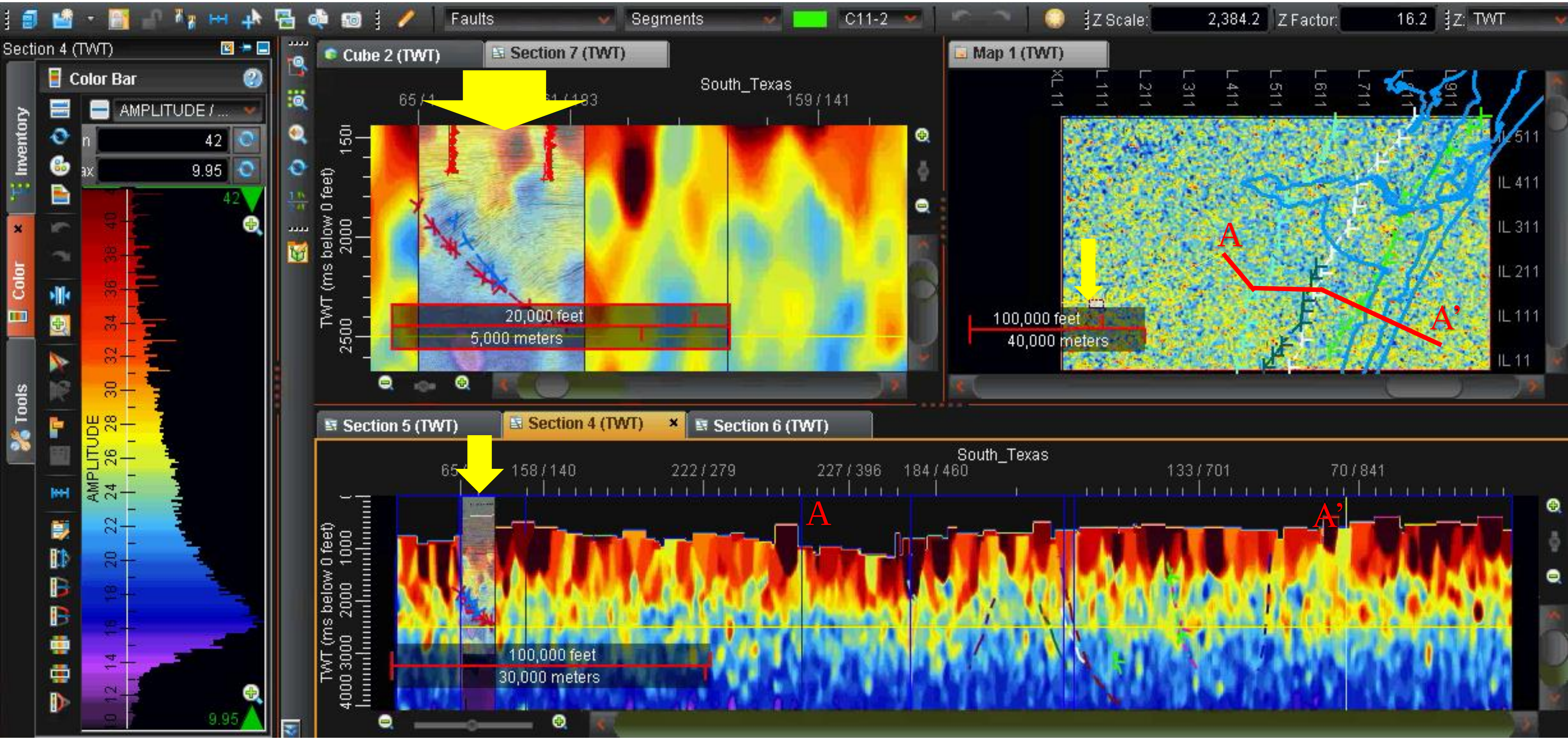
(Decimal fraction calendar year)

3 of 18 Lightning Attributes - Energy



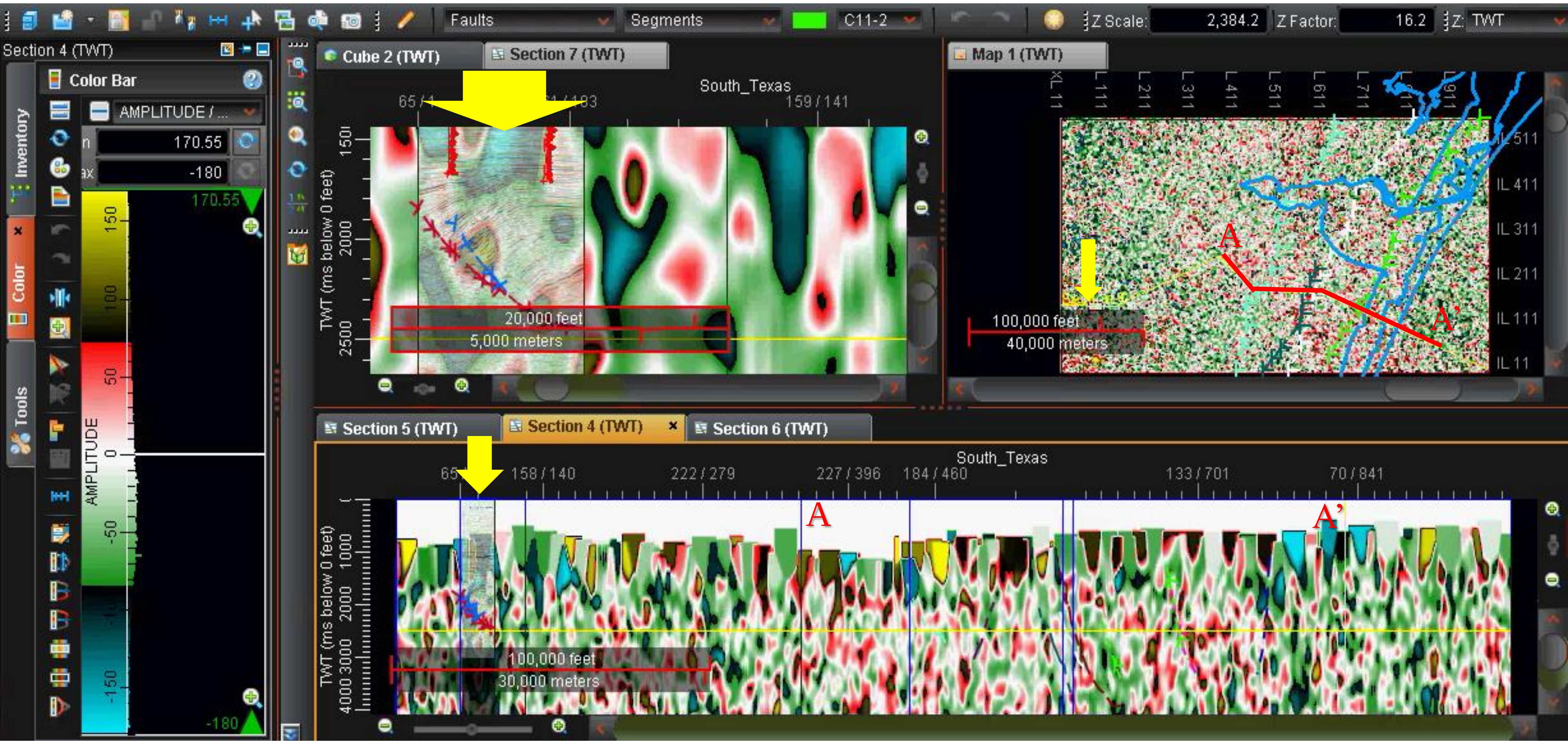
(milliampere-seconds)

4 of 18 Lightning Attributes - Frequency



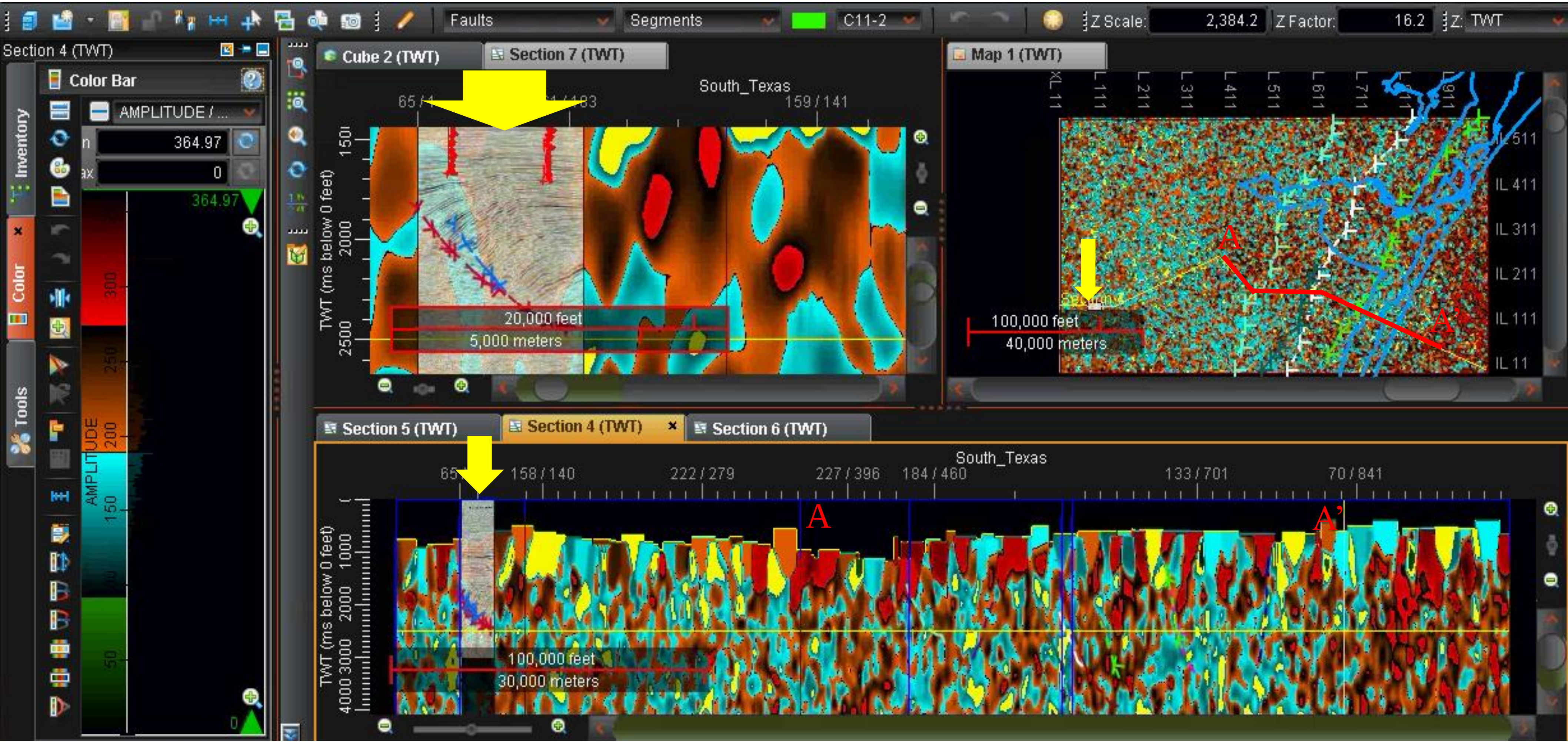
(kilohertz)

5 of 18 Lightning Attributes - Moon Local Longitude



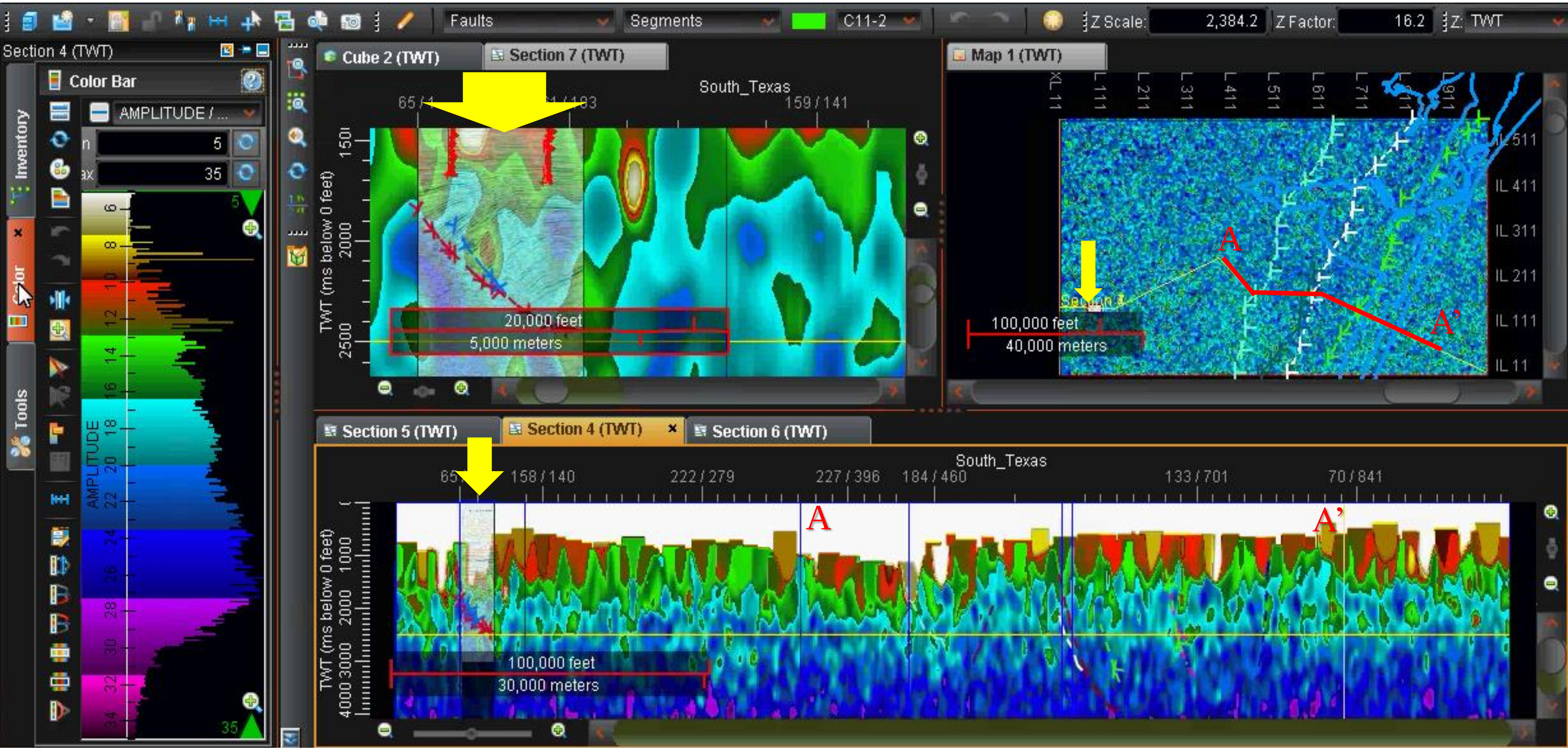
(degrees [-180 to 180]s)

6 of 18 Lightning Attributes - Moon Phase



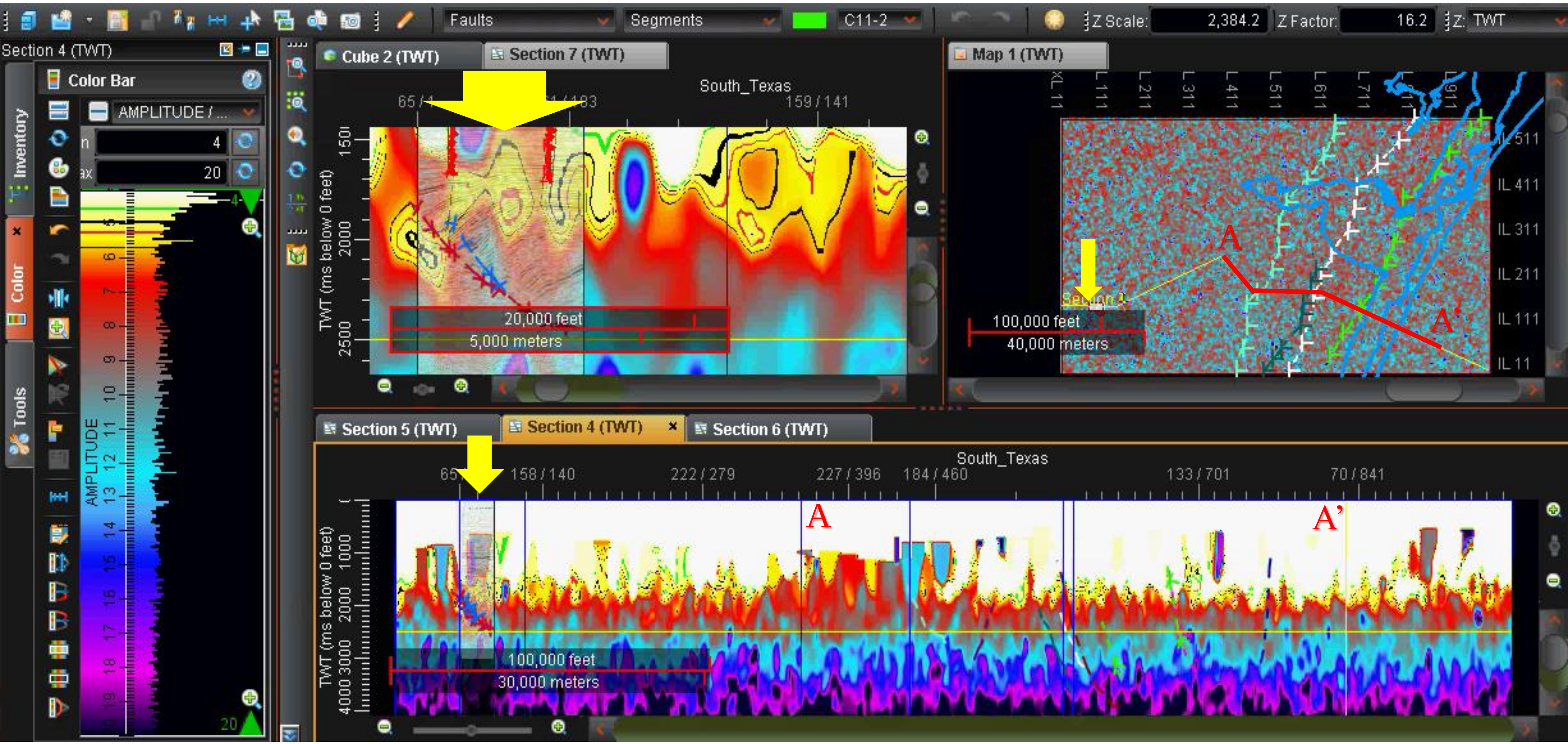
(degrees [0-360])

7 of 18 Lightning Attributes - Peak to Zero



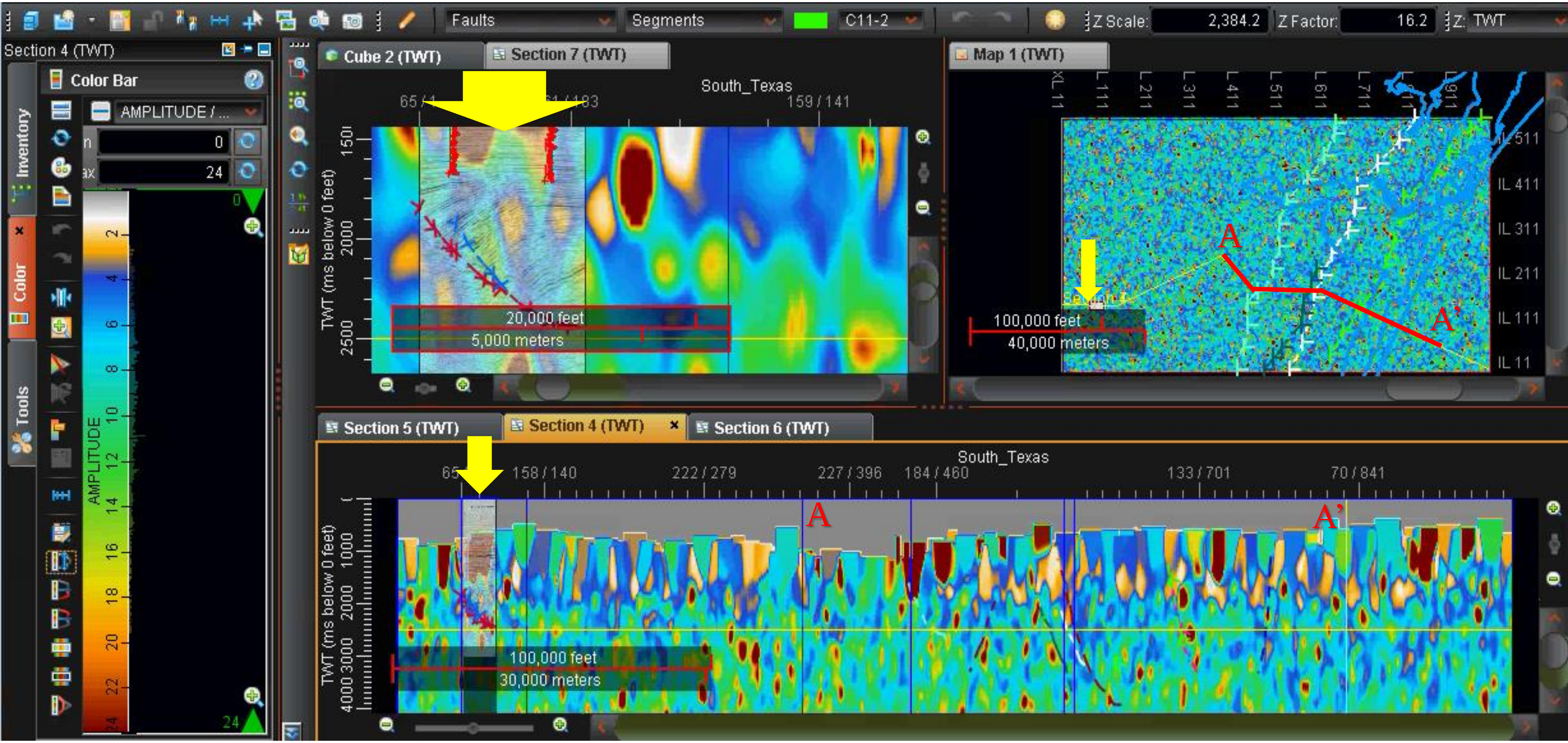
(microseconds)

8 of 18 Lightning Attributes - Peak Current



(kiloamperes)

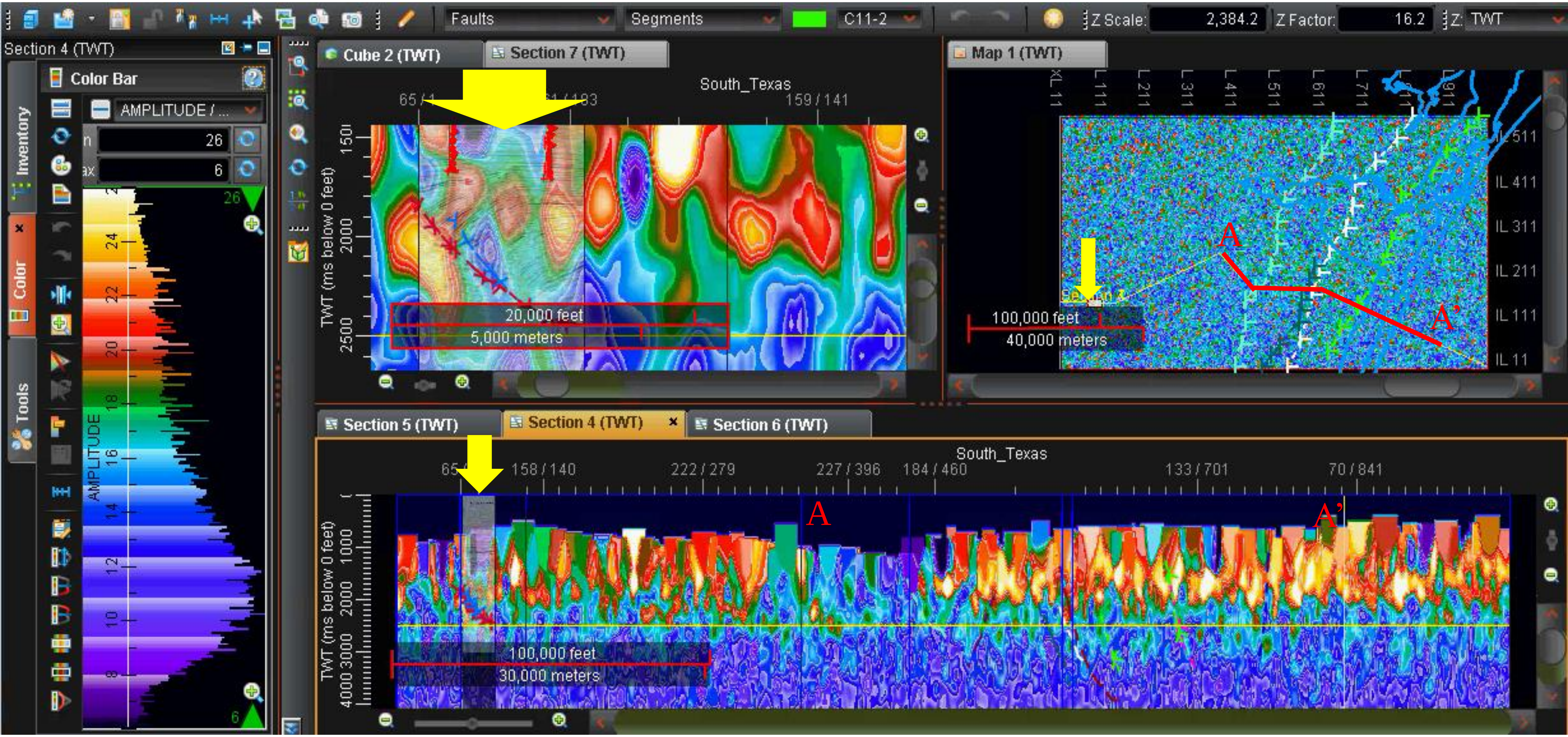
9 of 18 Lightning Attributes - Apparent Permittivity



(microfarads per meter)

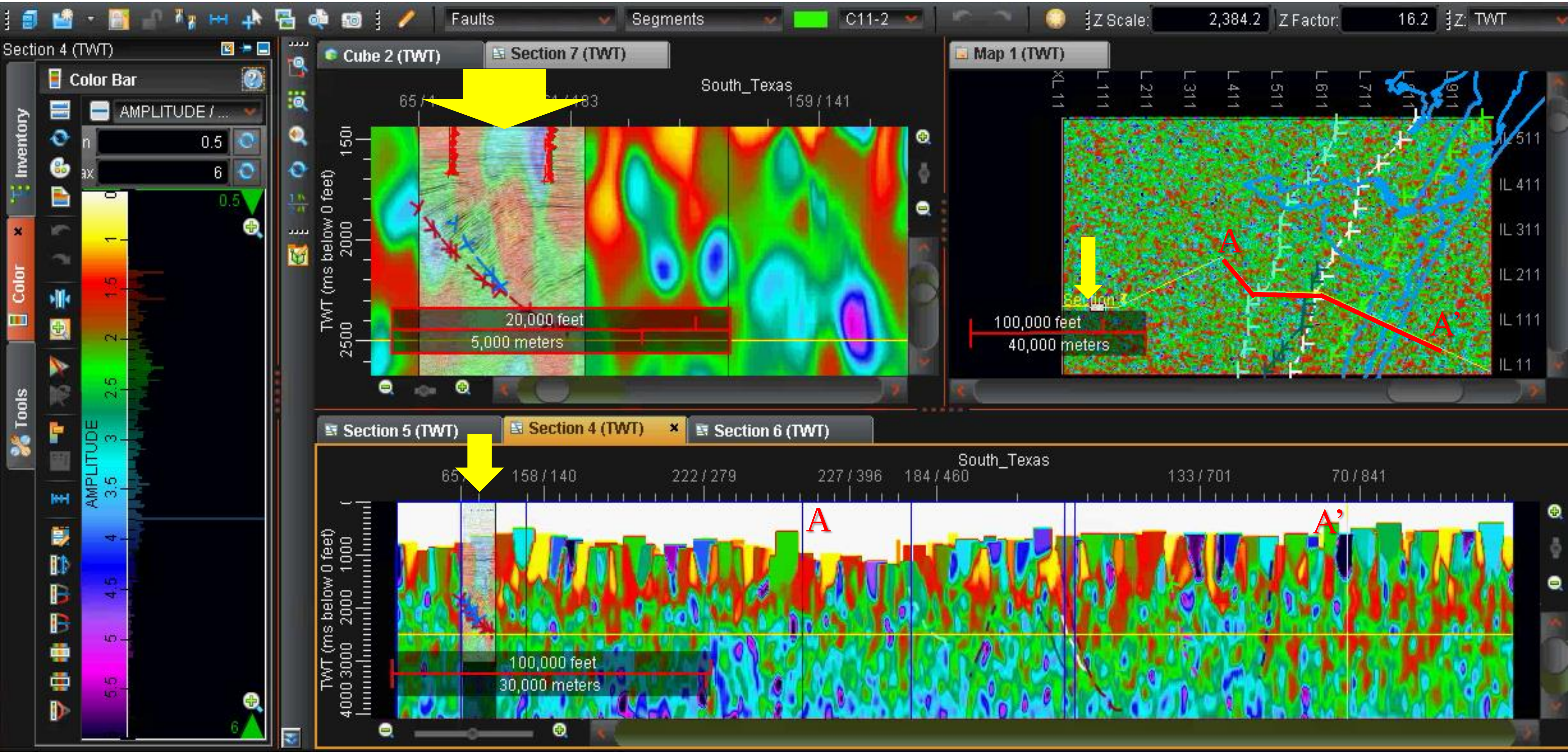
10 of 18 Lightning Attributes - Apparent Resistivity

Used to correlate Ewing's 1986 cross-sections



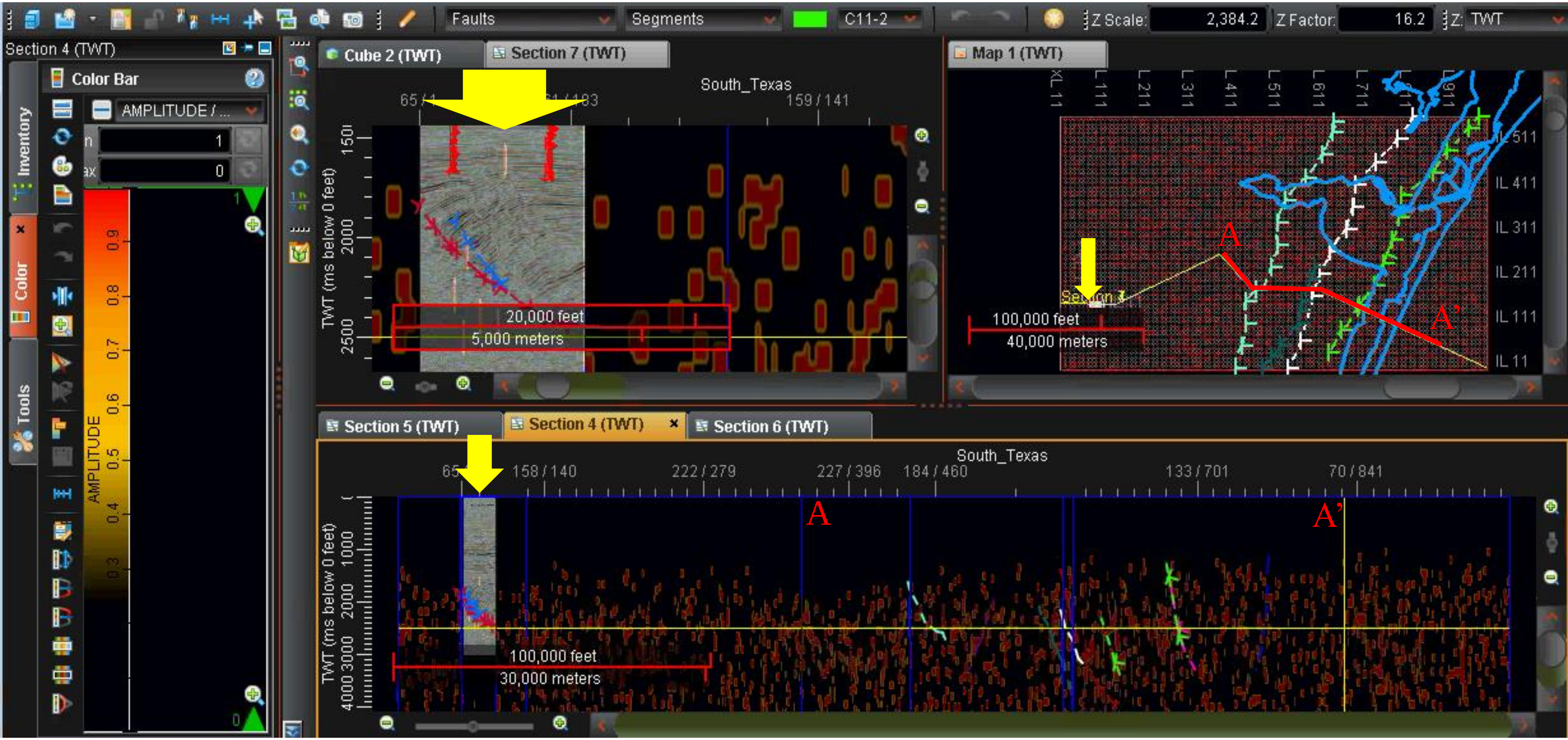
(ohm-meters)

11 of 18 Lightning Attributes - Rise Time



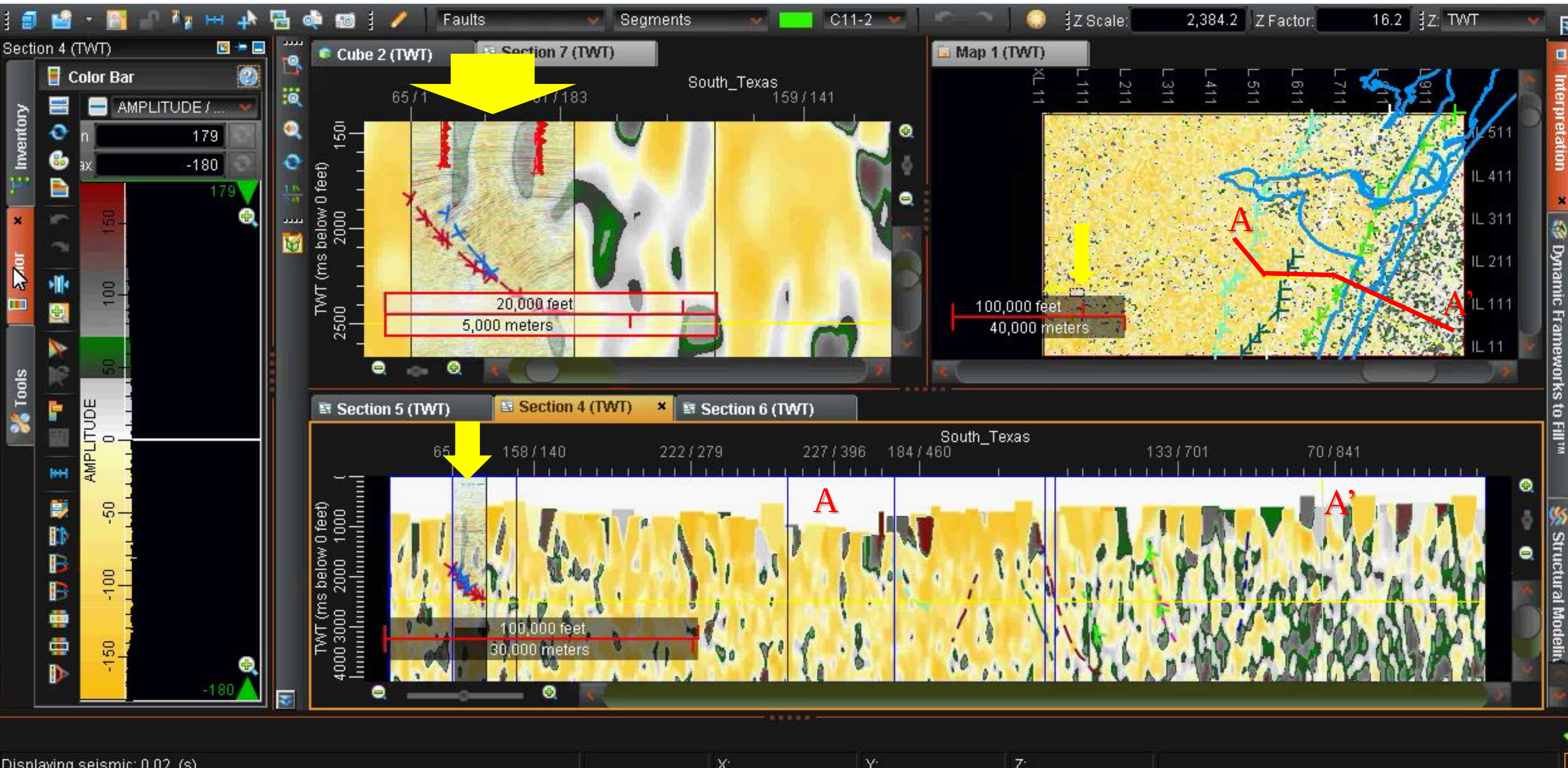
(microseconds)

12 of 18 Lightning Attributes - Spike



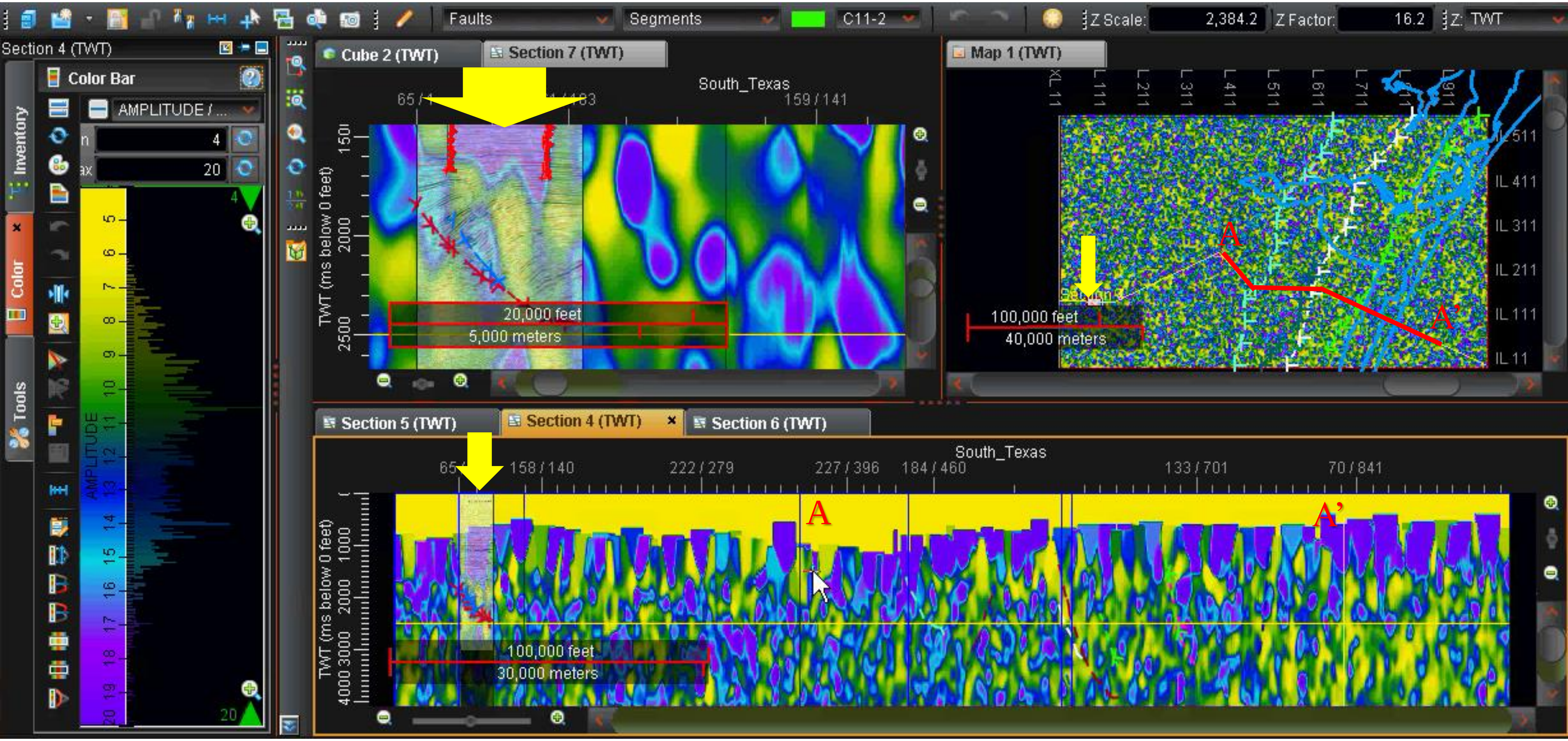
(position of strike)

13 of 18 Lightning Attributes - Sun Local Longitude



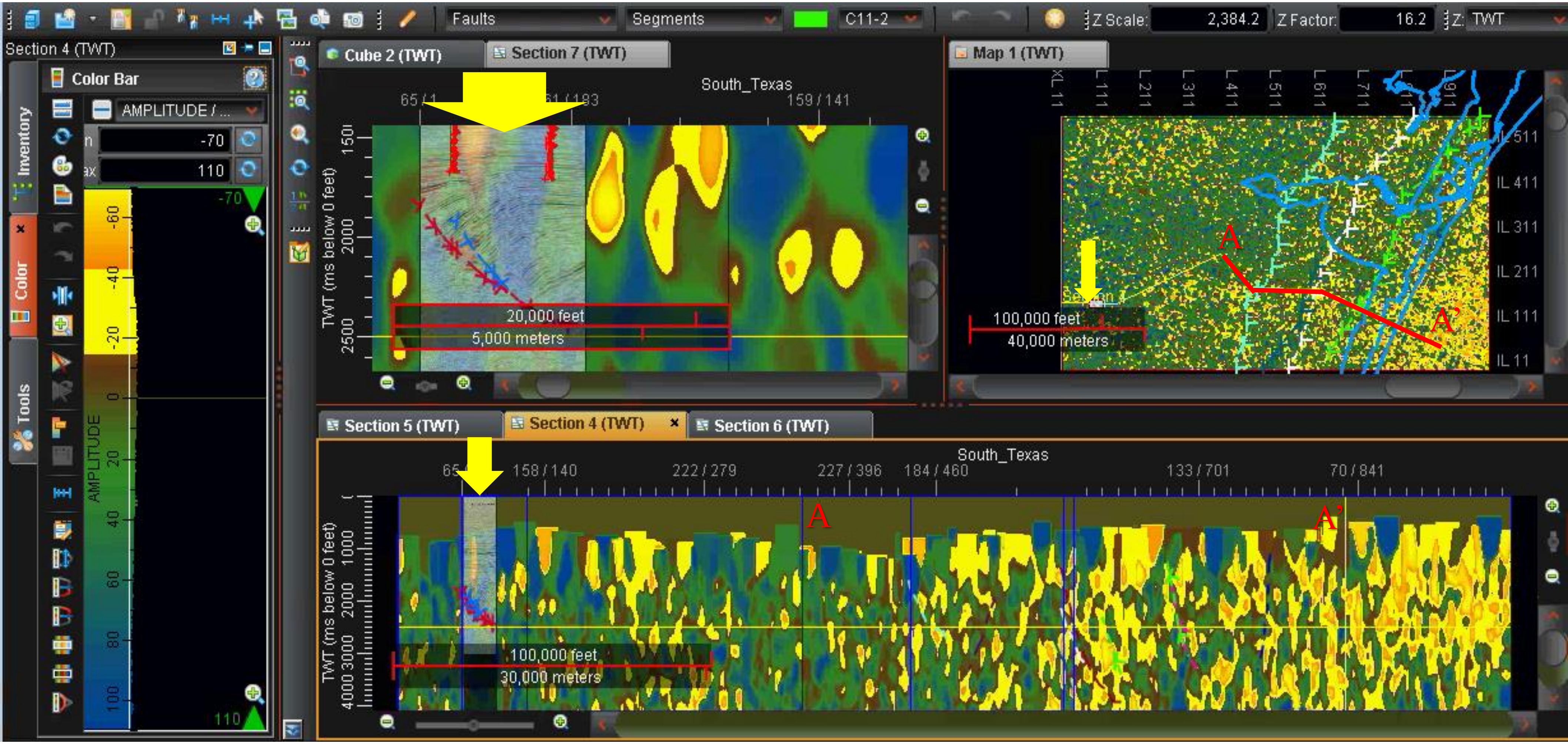
(degrees [-180 to 180])

14 of 18 Lightning Attributes - Symmetry



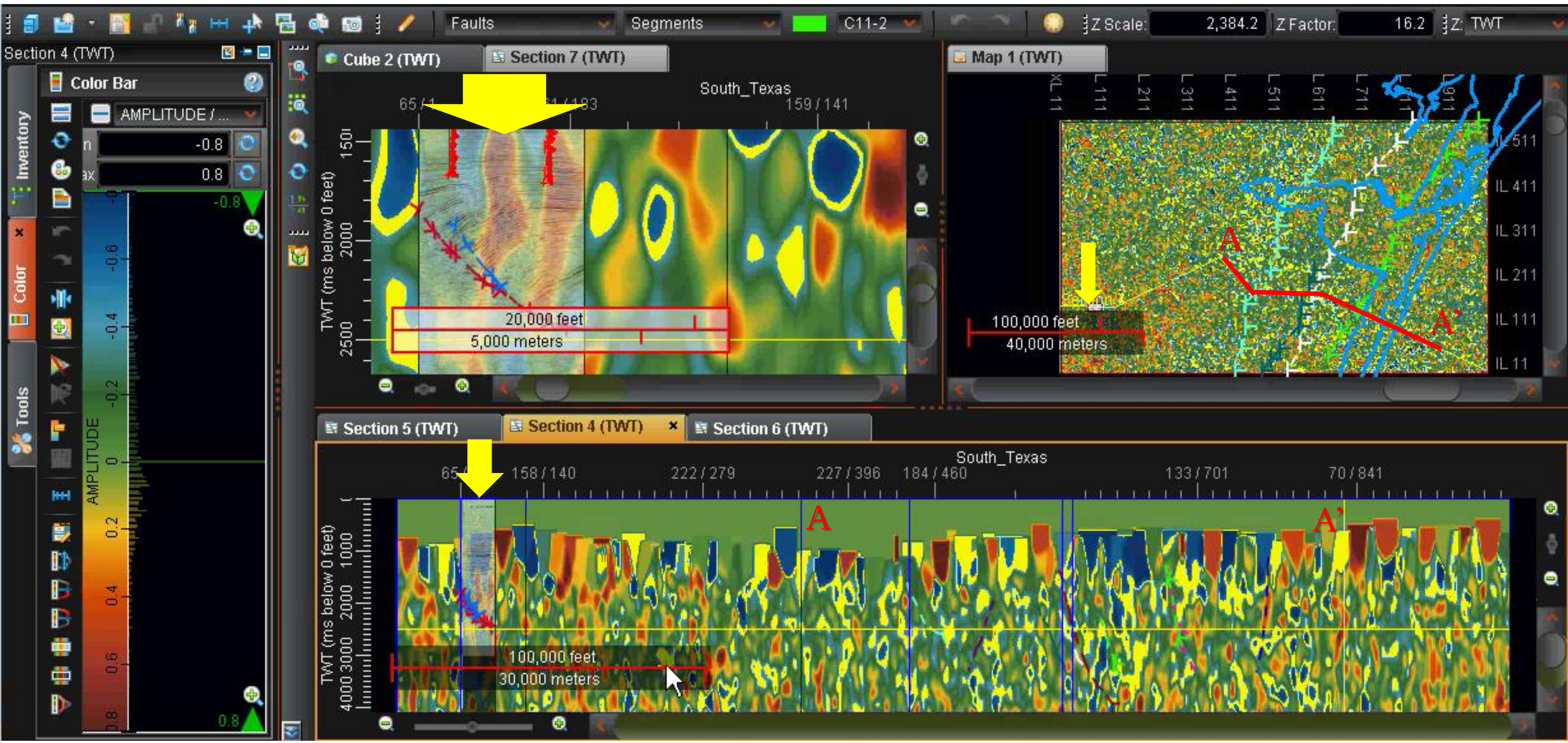
(% [<50: rt<pz; 50: rt=pz; >50: rt>pz])

15 of 18 Lightning Attributes - Tidal Gravity



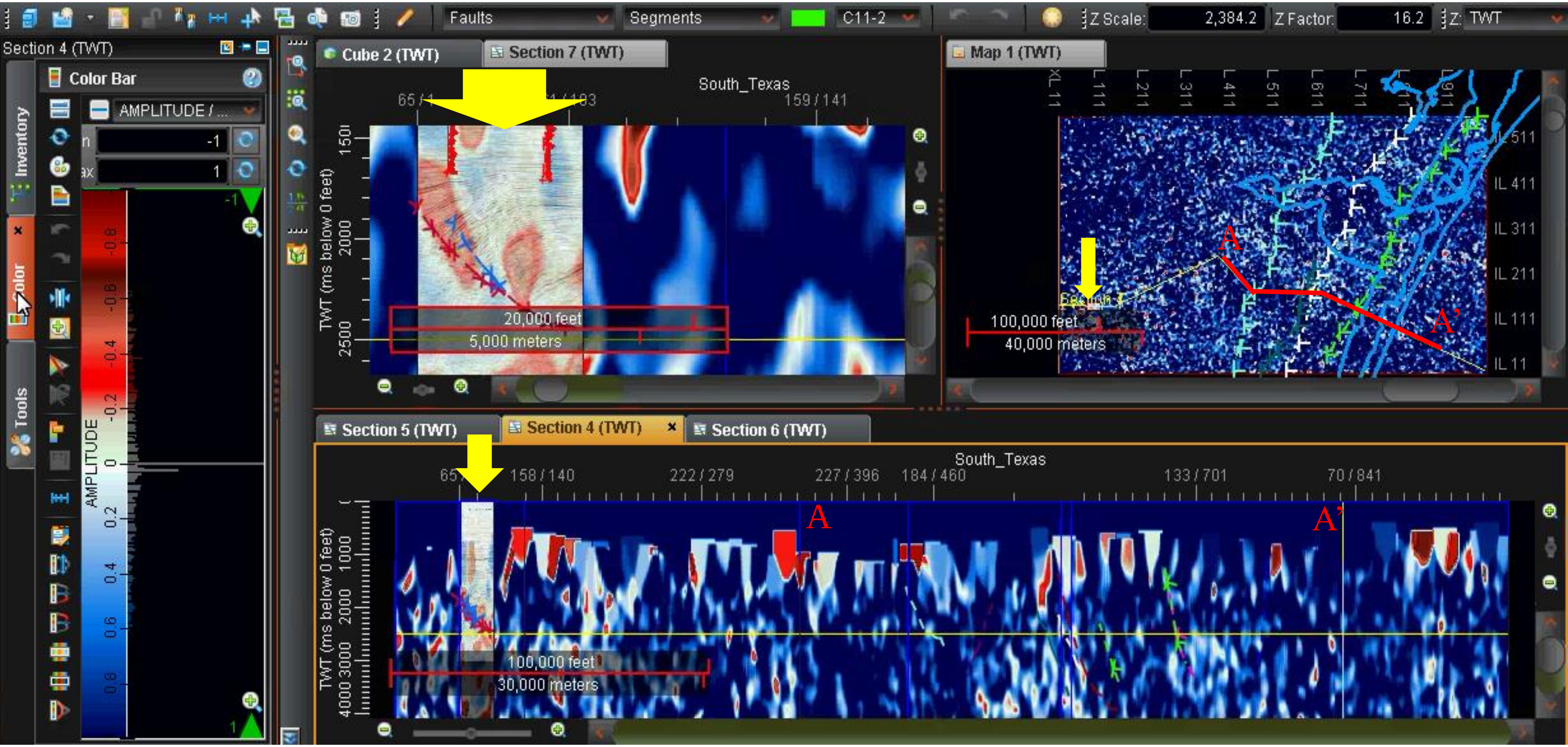
(microgals)

16 of 18 Lightning Attributes - Tide



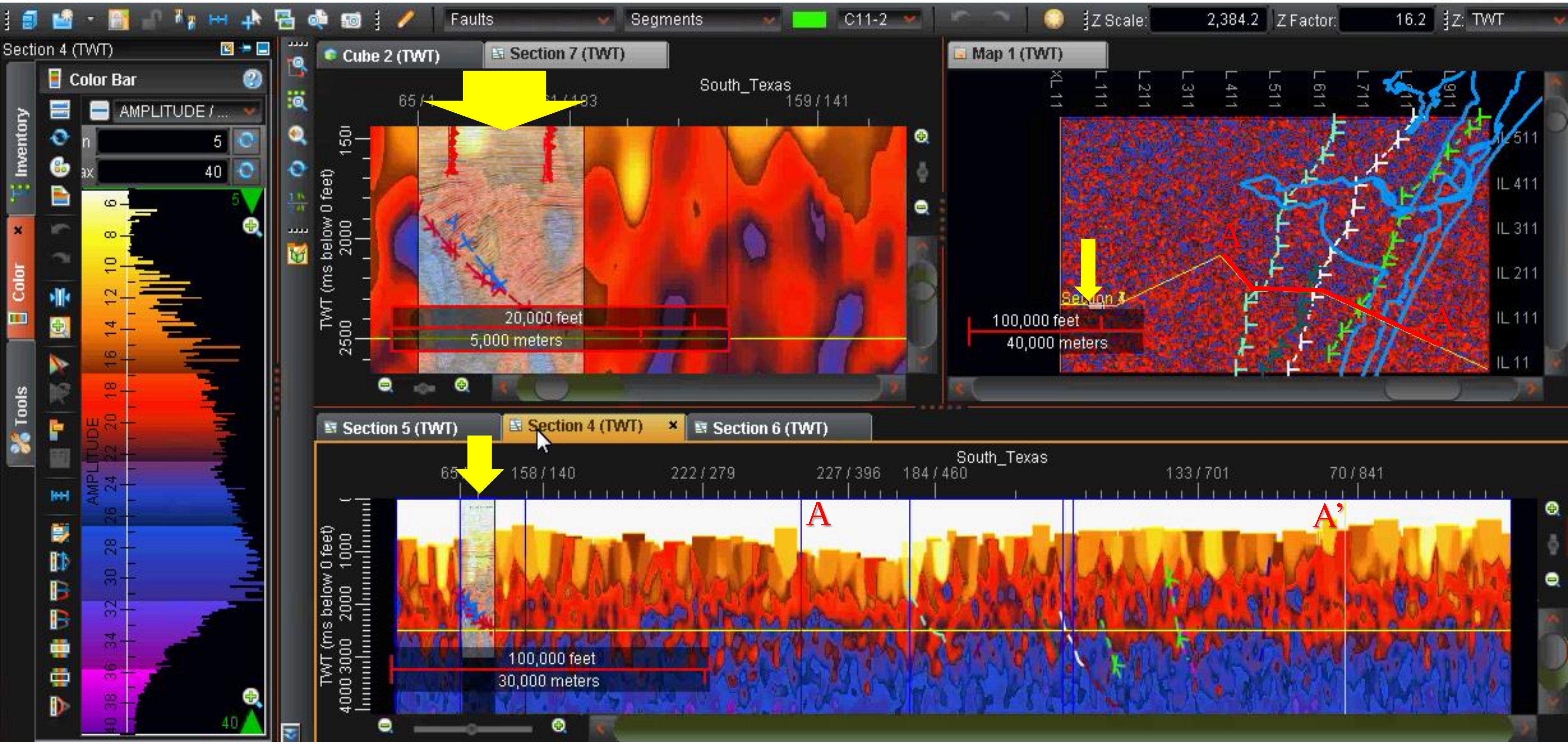
([-1.0: low spring tide; 0.0: mean tide; 1.0: high spring tide])

17 of 18 Lightning Attributes - Tide Gradient



(first derivative of Tide)

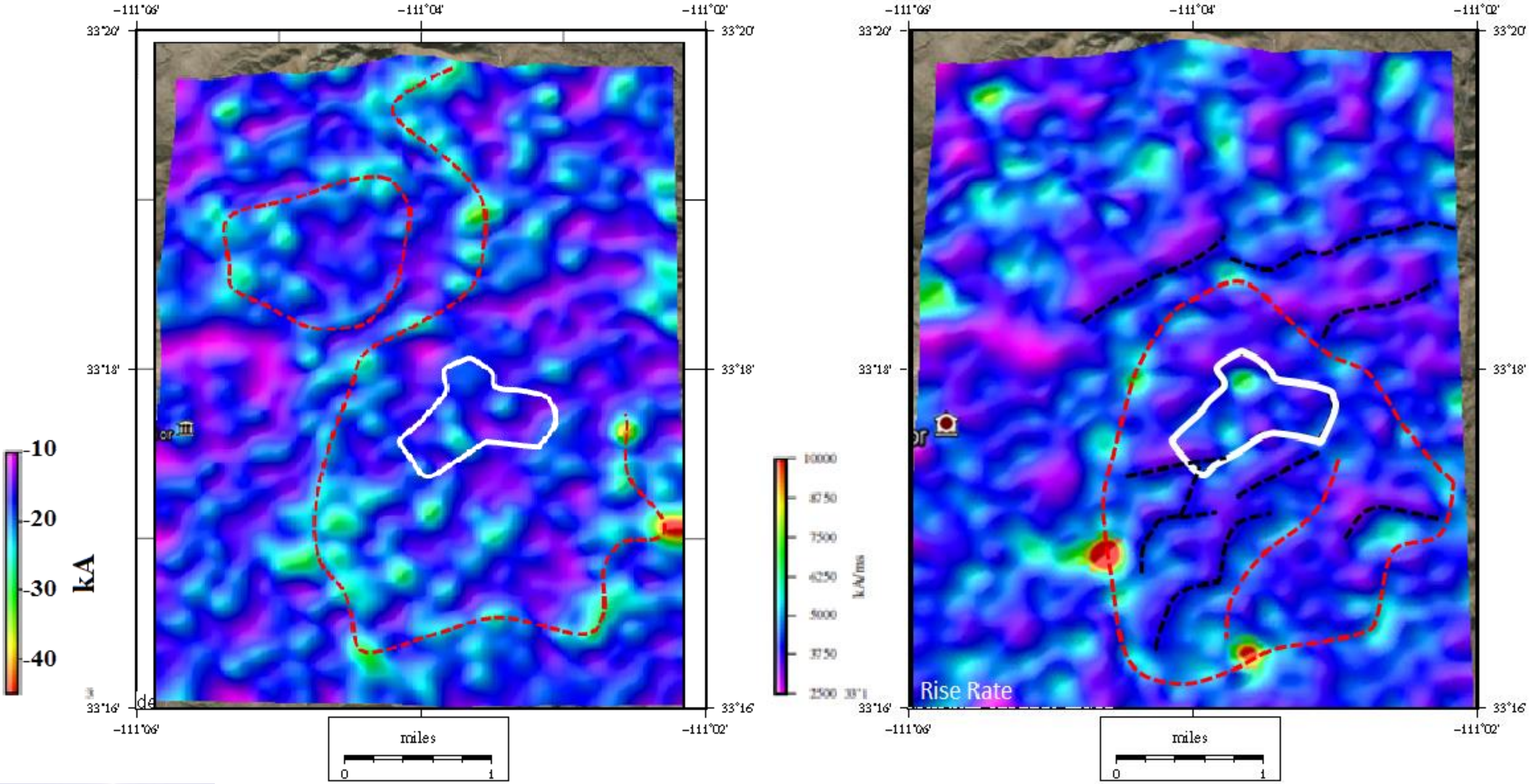
18 of 18 Lightning Attributes - Total-Wavelet Time



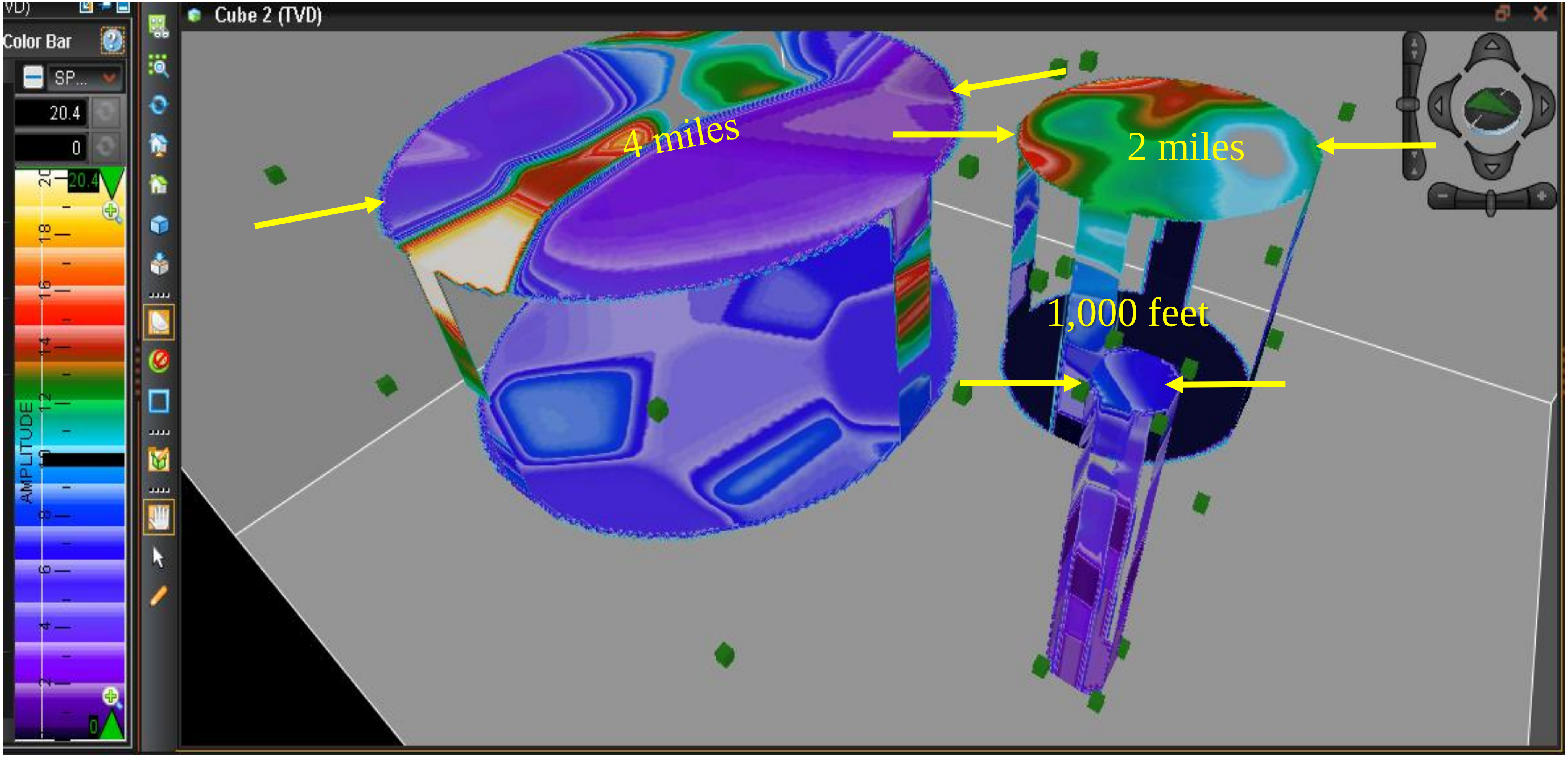
(microseconds)

5a. Arizona Examples: Resolution Copper

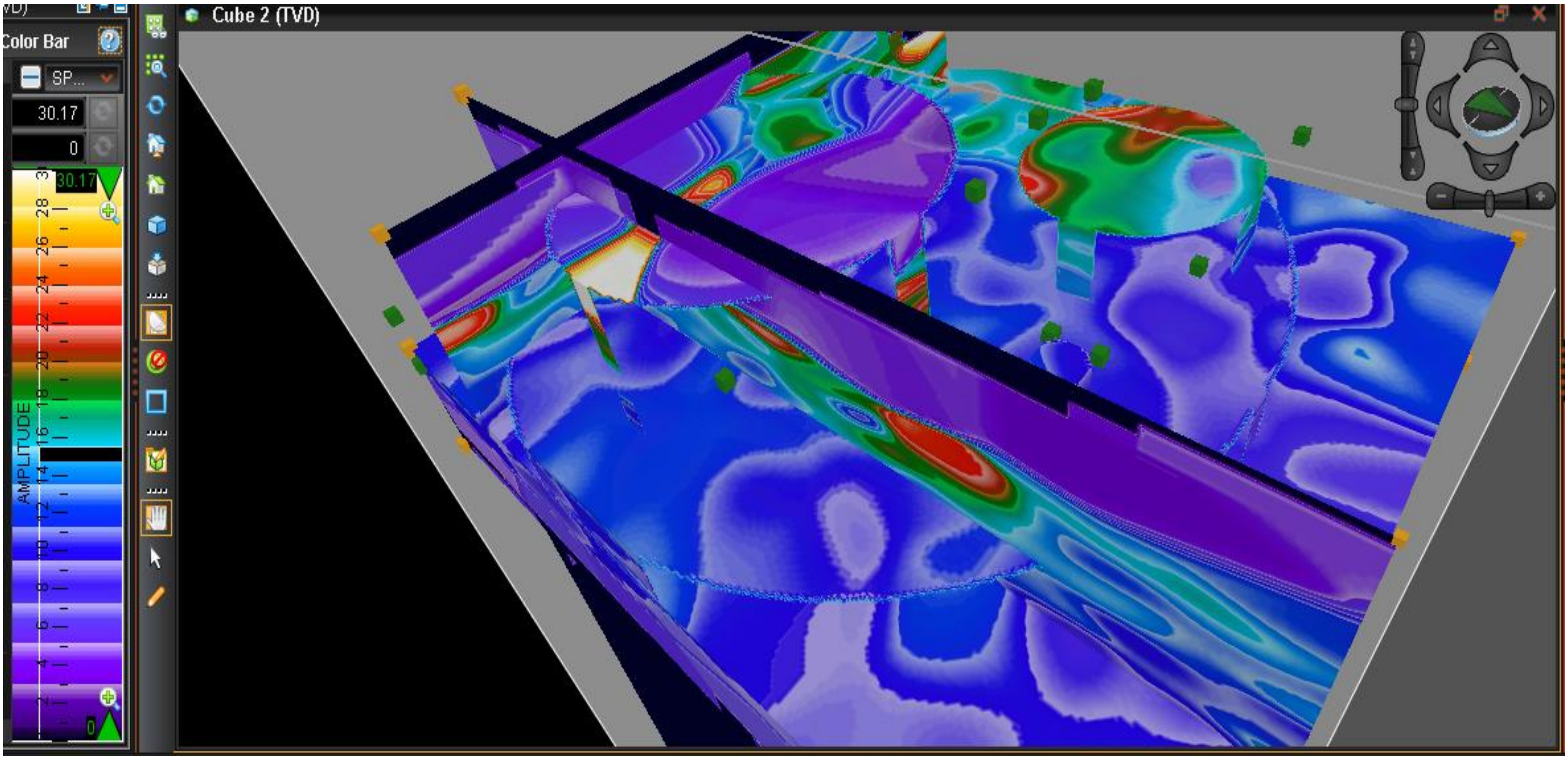
NLDN Peak Current & Rise-Rate



3 Example SPOT[SM]
Apparent-Resistivity Cylinders

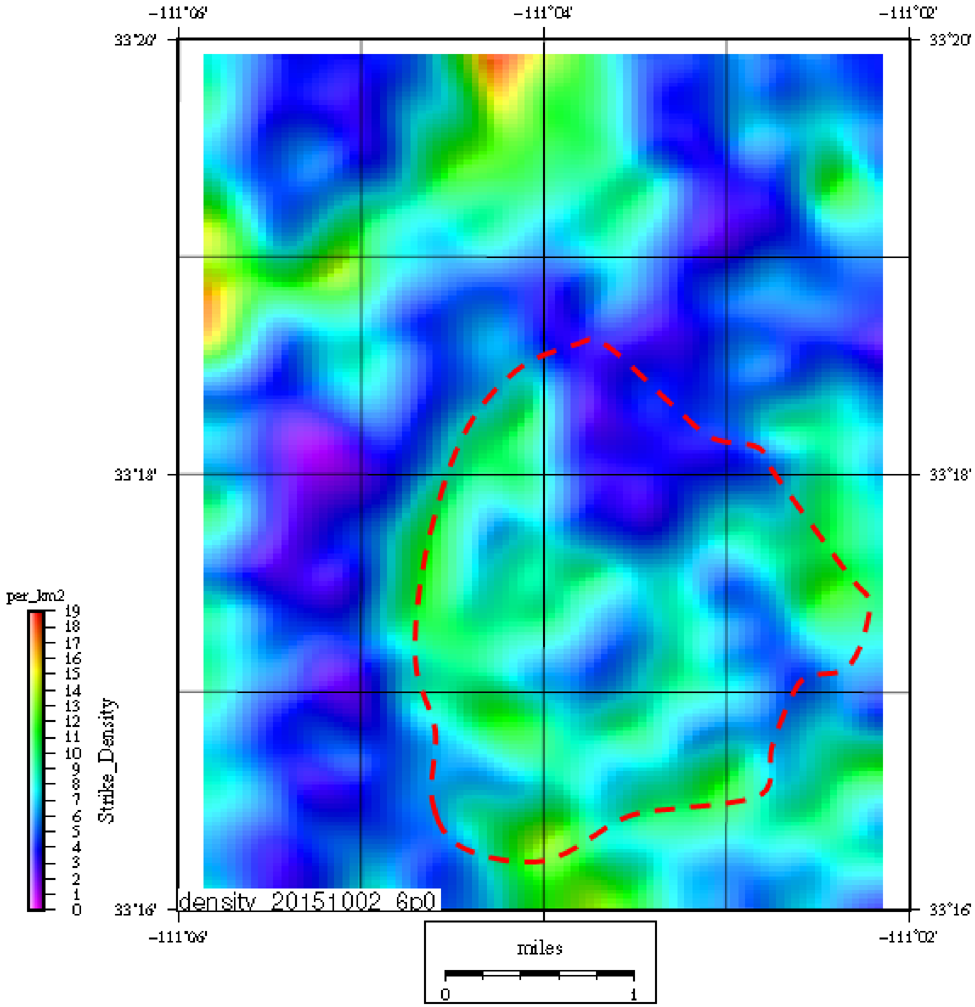


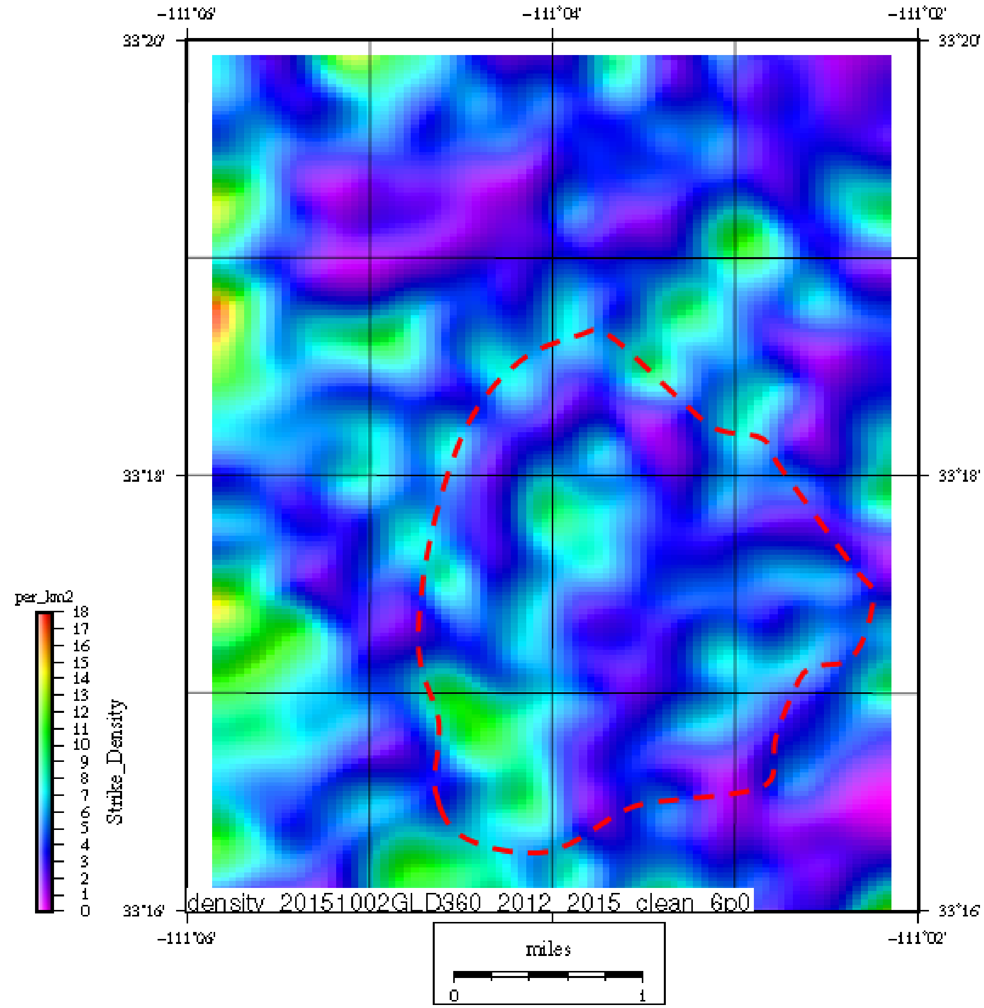
Integrating Resistivity in Three-Dimensions



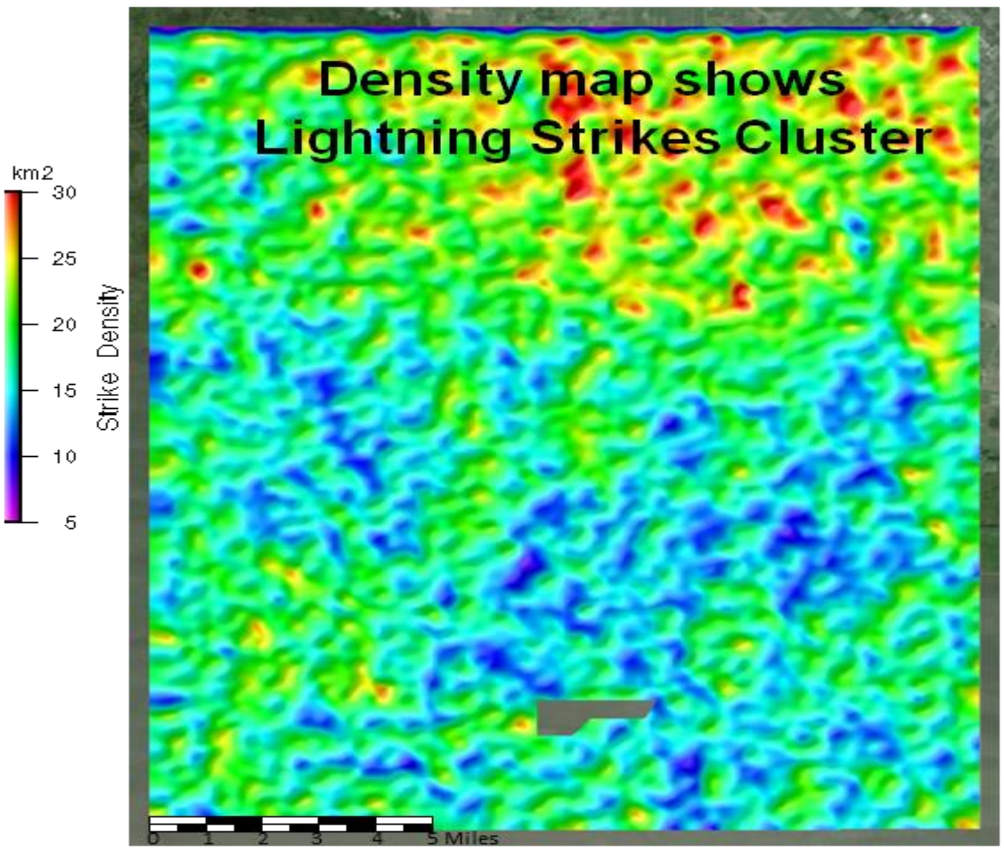
Comparing NLDN and GLD-360 data

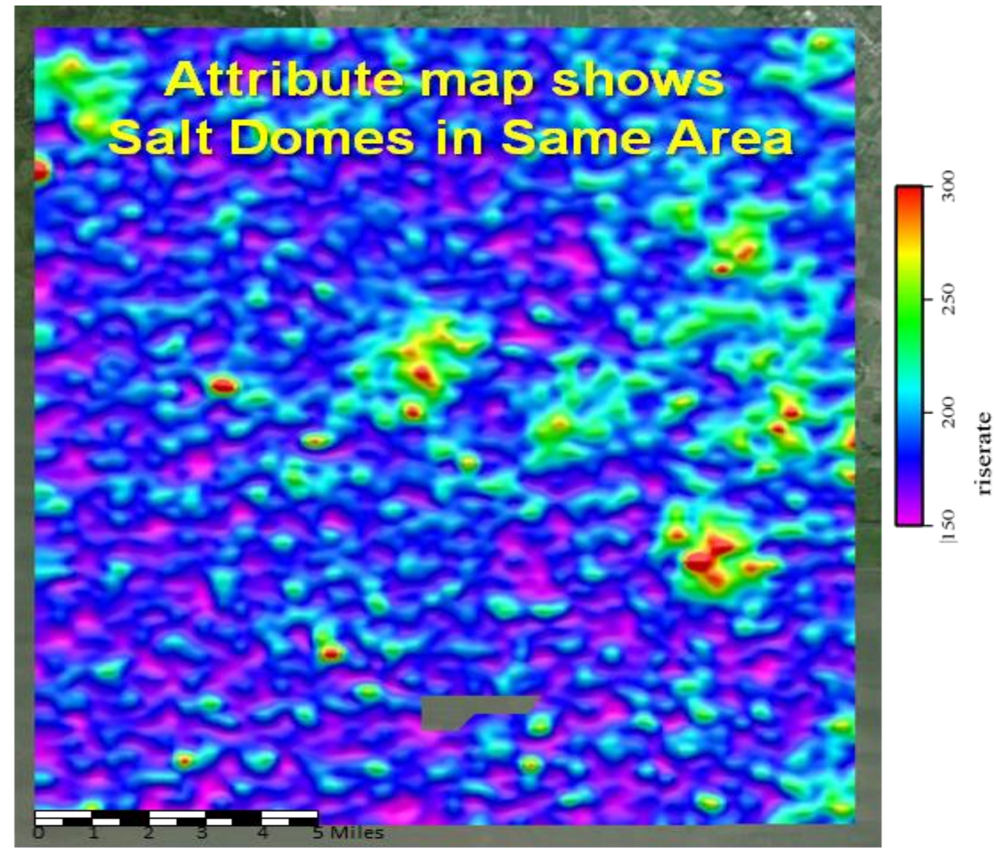
NLDN Density 1998-2015 & GLD-360 Density 2012-2015





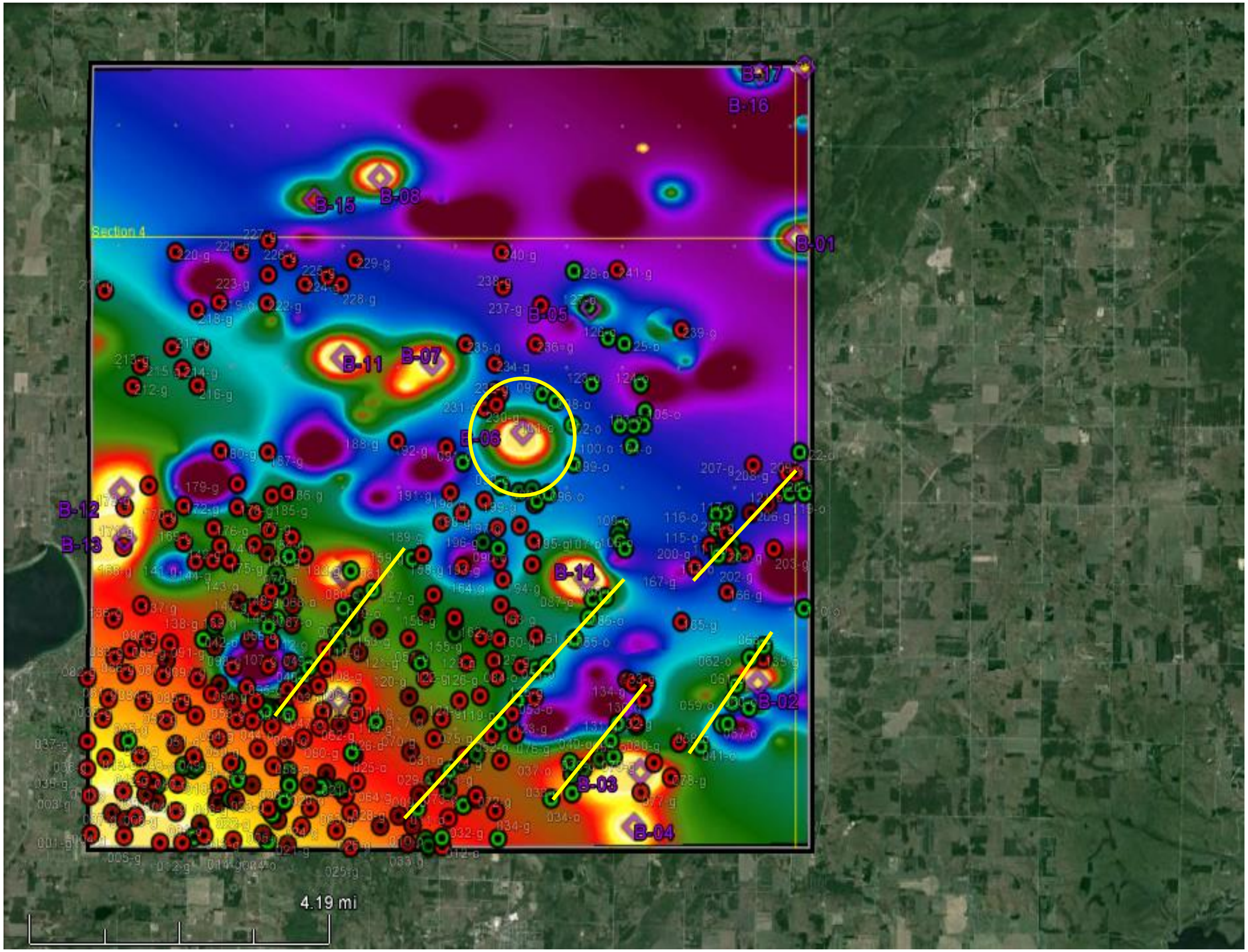
5b. Louisiana Example



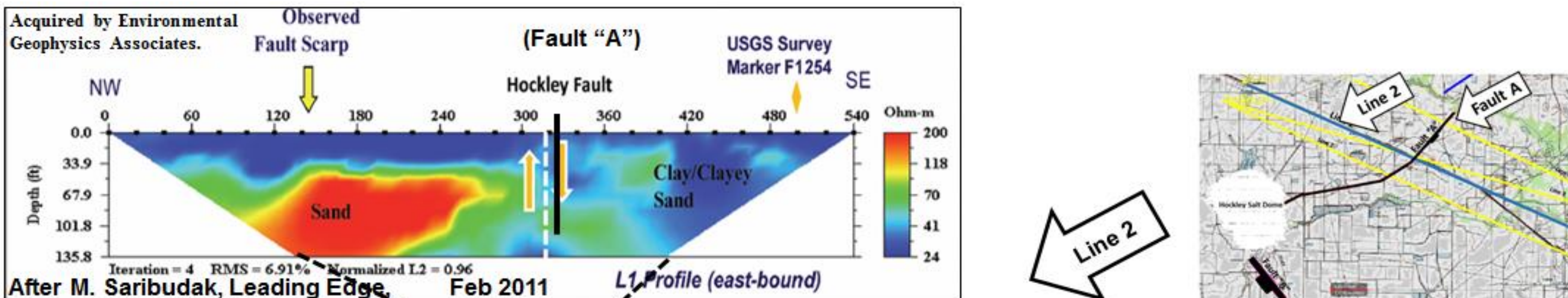


Density Map & Rate-of-Rise-Time Map

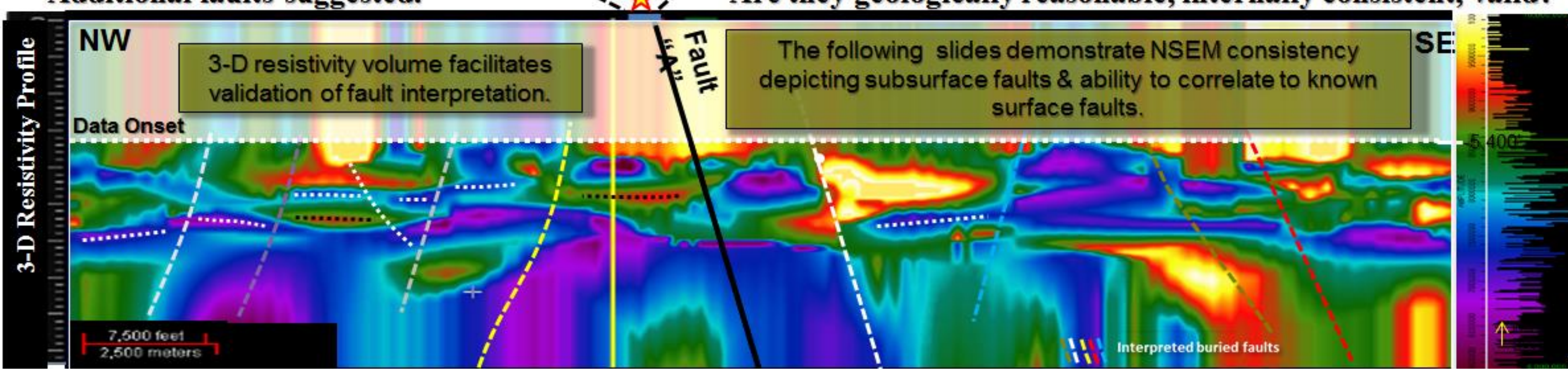
5c. Michigan Example
High Resistivity to SW on B-2 Horizontal-Slice
with Oil & Gas Wells in Analysis Area posted (note lineaments)



5d. One Last Texas Example



Additional faults suggested. Are they geologically reasonable, internally consistent, valid?



2-D Resistivity Survey ties Lightning-Derived Resistivity Cross-Section

References

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