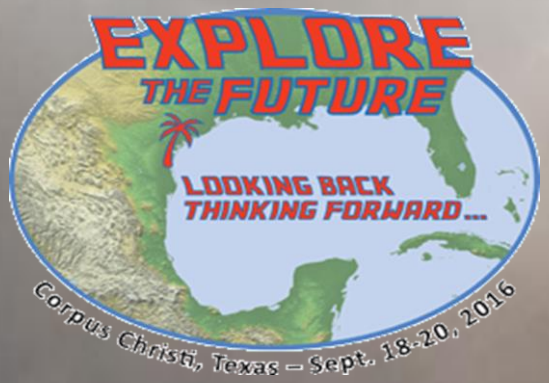


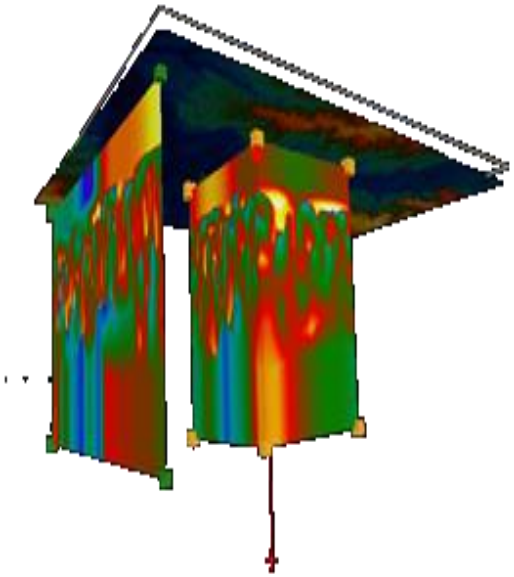
DYNAMIC MEASUREMENT

New Lightning Attribute Volumes Compared to the BEG's Stratton 3D Seismic Survey

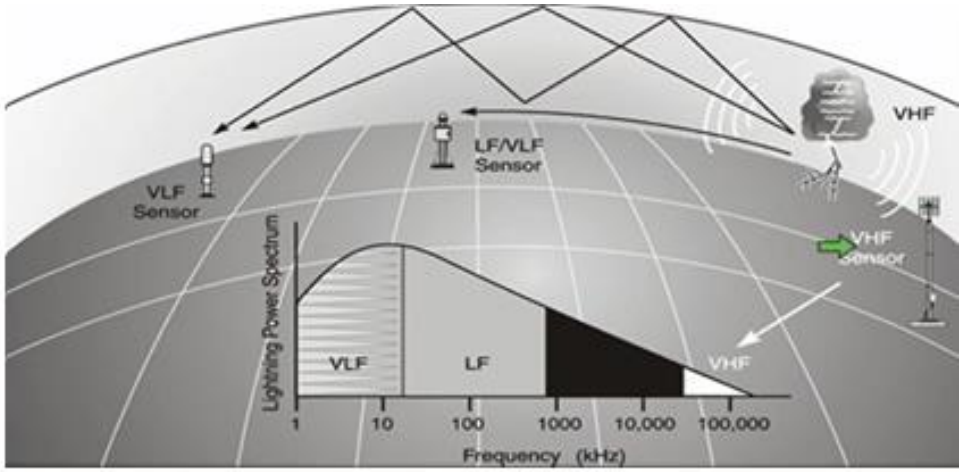
Kathleen S. Haggar, Les R. Denham, and
H. Roice Nelson, Jr.
Dynamic Measurement LLC
19 September 2016

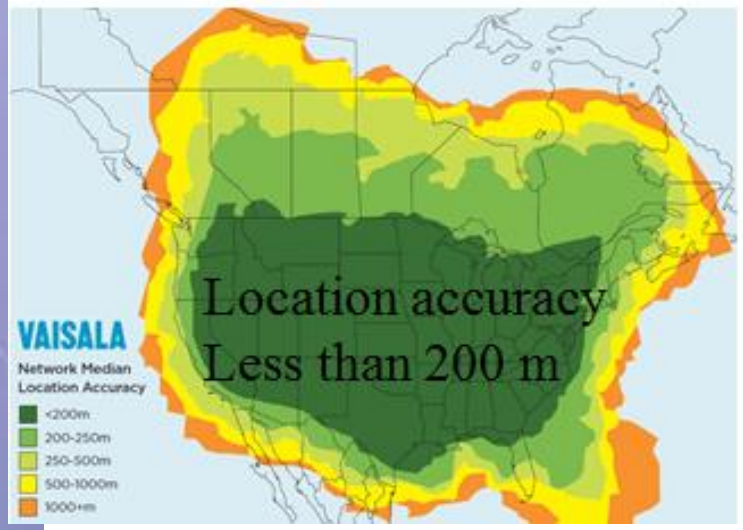
Introduction

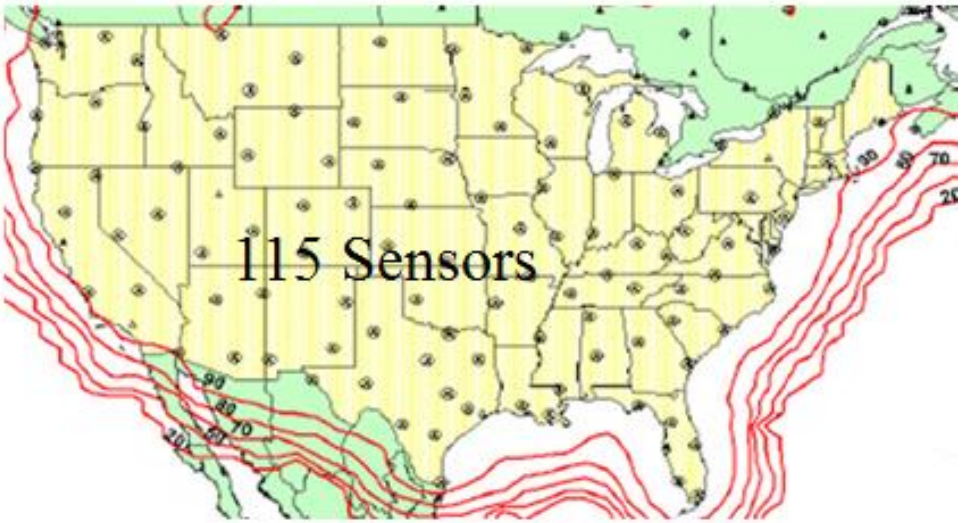
- **Lightning Facts and Theory**
- **Lightning Analysis and New Attributes**
- **Applications of Lightning Technology**
- **Summary**



Vaisala's Established Lightning Detection Networks

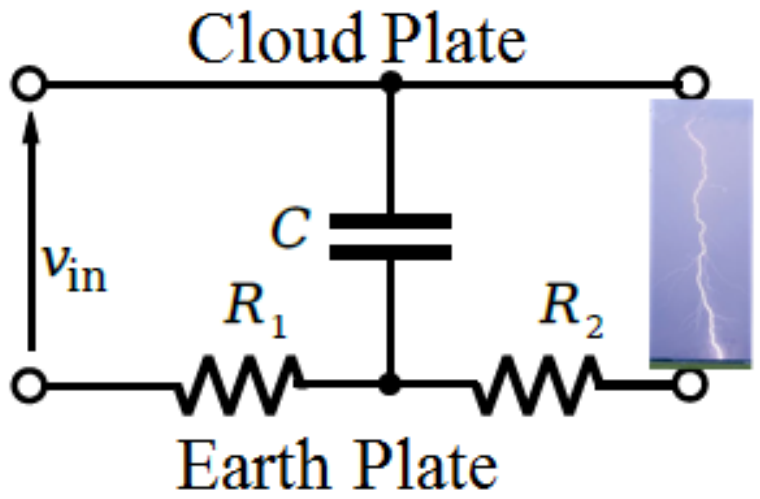






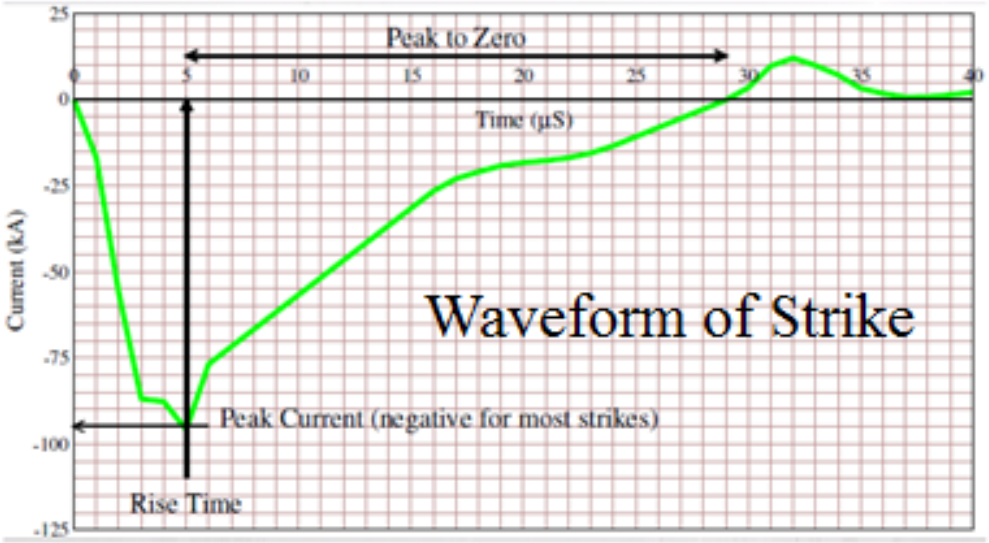
Vaisala: Martin Murphy Webinar 2016 used with permission.

Lightning Theory



Lightning physics is somewhat like a neon-tube relaxation oscillator.

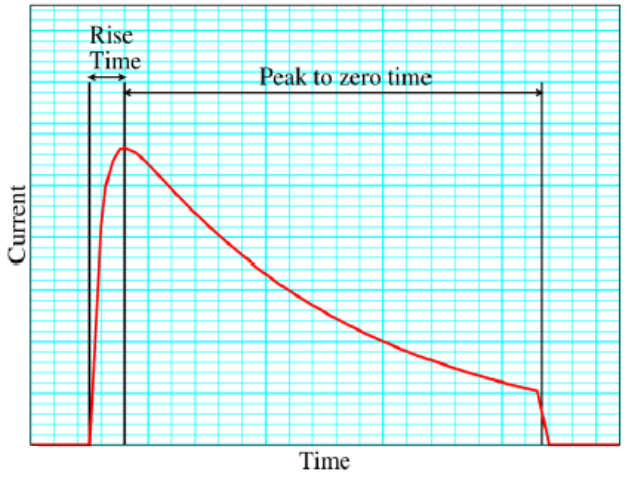
- Voltage builds across a capacitor until the insulating gas ionizes and becomes a conductor.
- R1 allows for charge and recharge
- R2 allows for the strike.



Electrostatic pulse emitted by lightning strike is recorded by sensors. Each strike has a unique waveform.

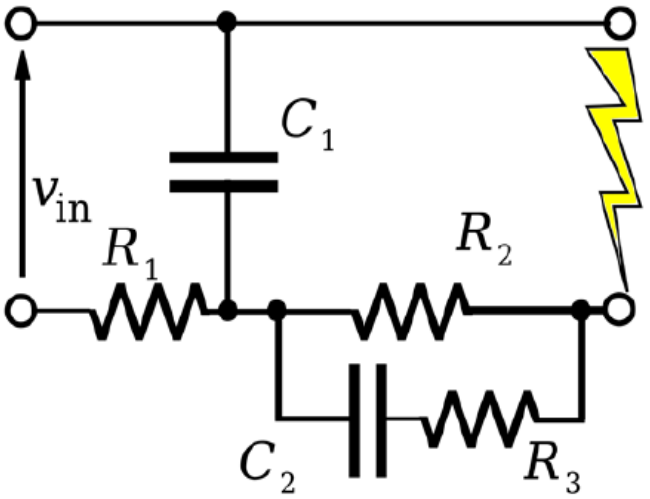
Lightning Attributes are derived from measured and computed values.

Lightning and the Induced Polarization Effect



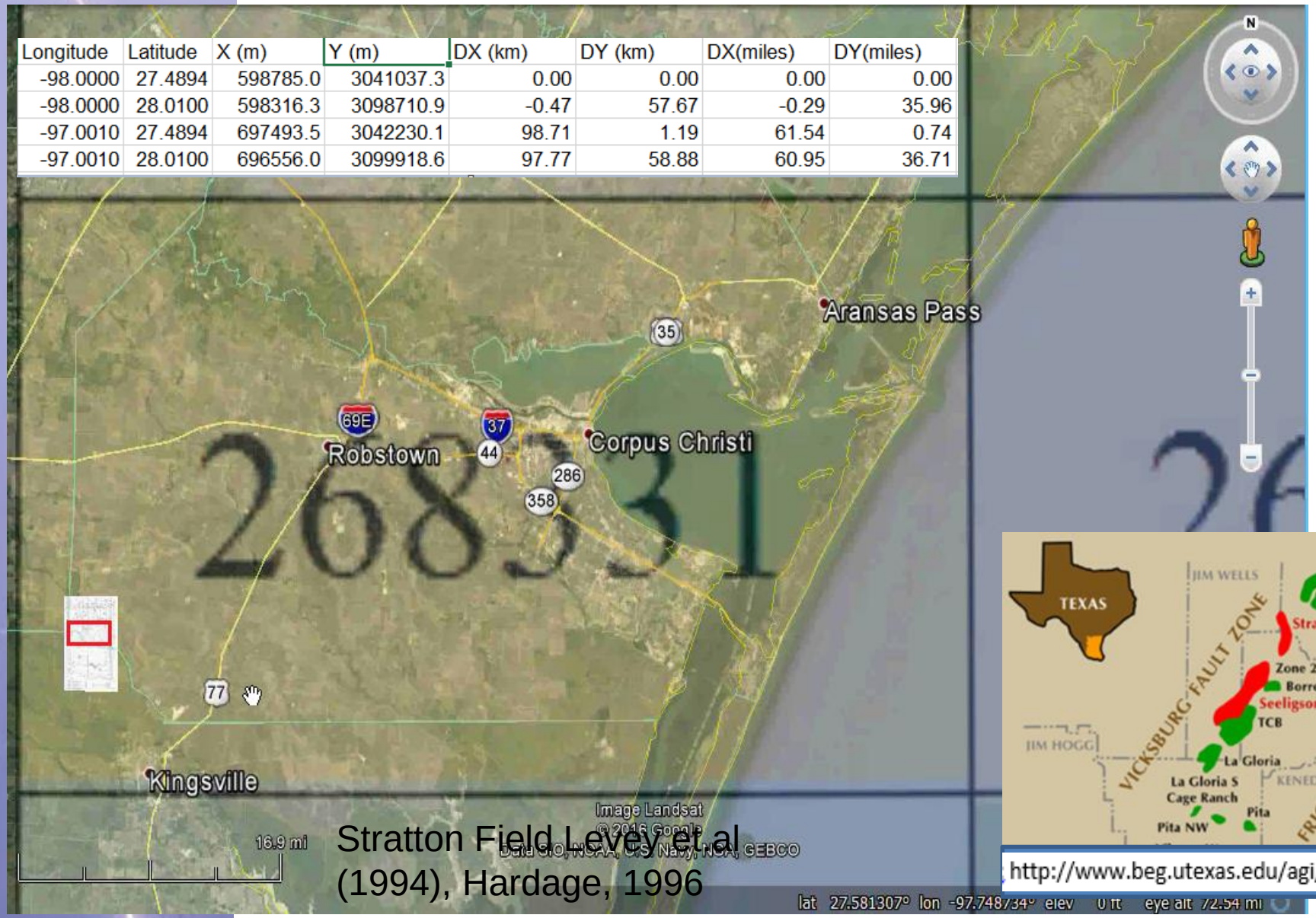
- Lightning does not have a square waveform
- But it does have a very steep onset
- Variations in the onset as measured (rise-time) show the IP Effect

- 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



Study Area Infinite Grid(SM) Cell No. 268331

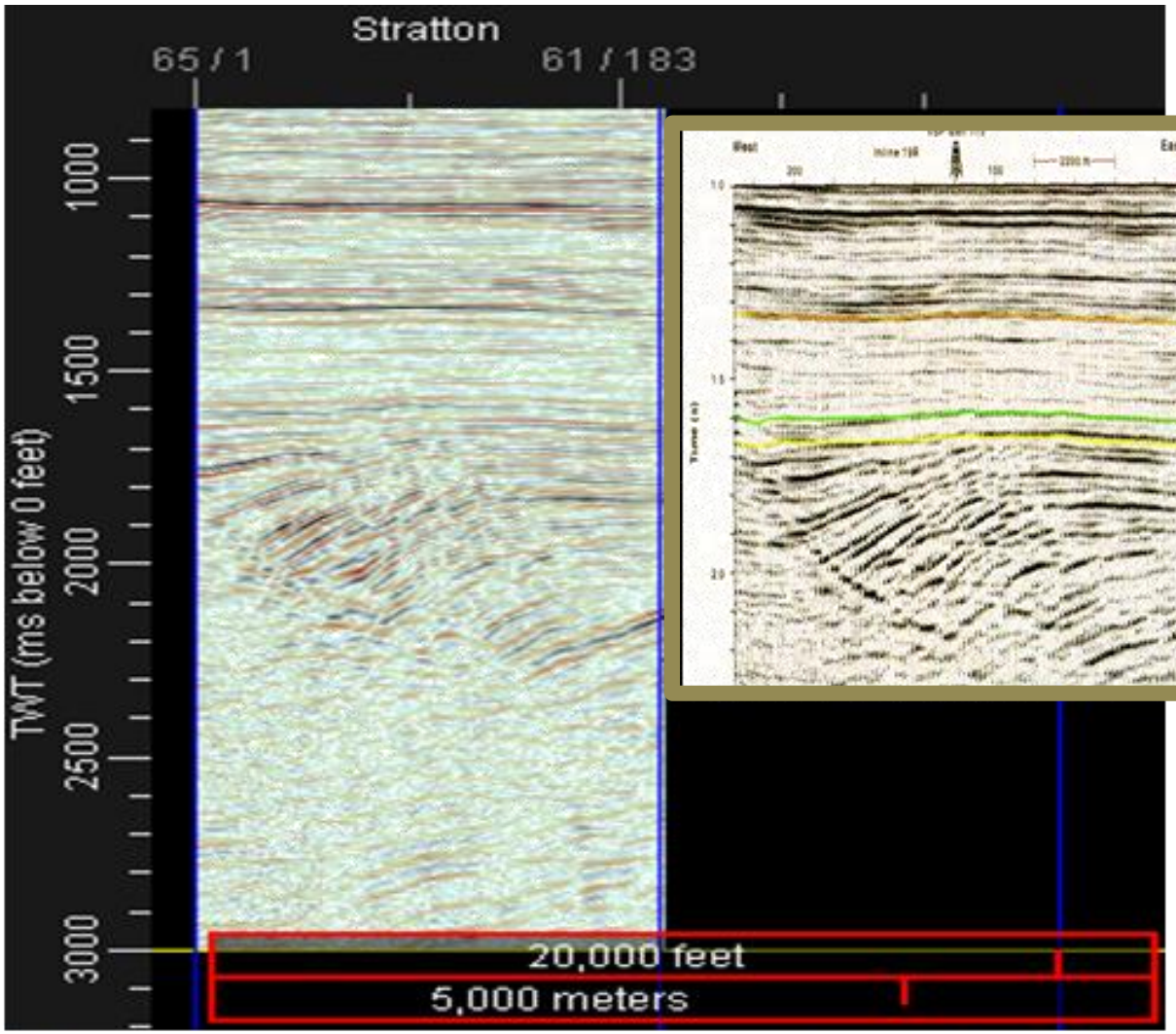
Longitude	Latitude	X (m)	Y (m)	DX (km)	DY (km)	DX(miles)	DY(miles)
-98.0000	27.4894	598785.0	3041037.3	0.00	0.00	0.00	0.00
-98.0000	28.0100	598316.3	3098710.9	-0.47	57.67	-0.29	35.96
-97.0010	27.4894	697493.5	3042230.1	98.71	1.19	61.54	0.74
-97.0010	28.0100	696556.0	3099918.6	97.77	58.88	60.95	36.71



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

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

Stratton Seismic Sections



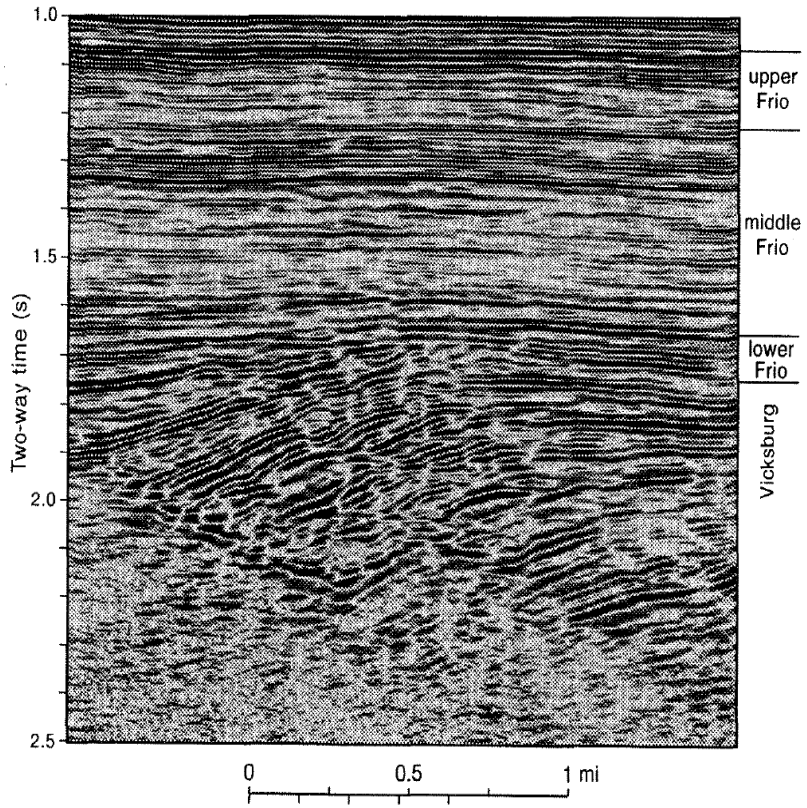
Frio Horizons
Fluvial – Deltaic
Sands

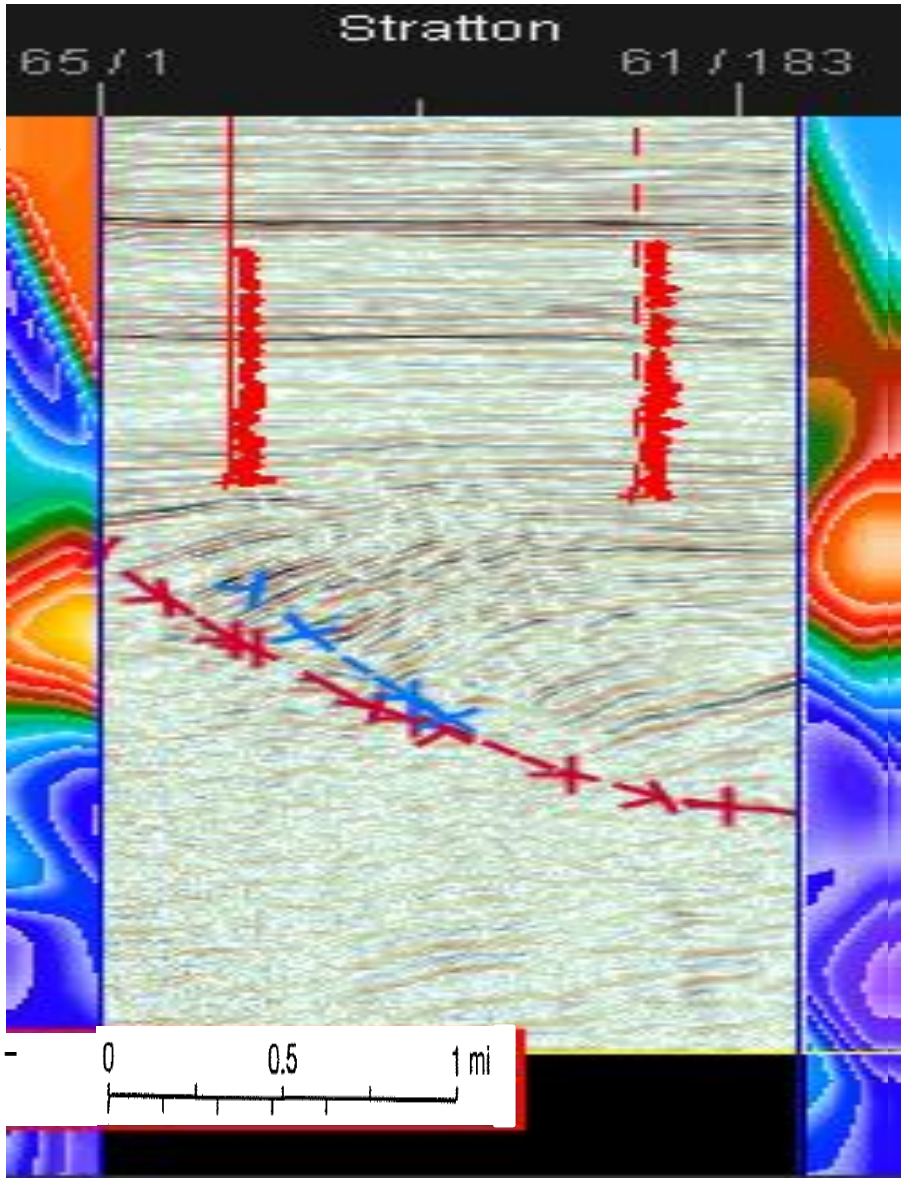
Frio
Horizons

Public Stratton Seismic to 3.0 seconds

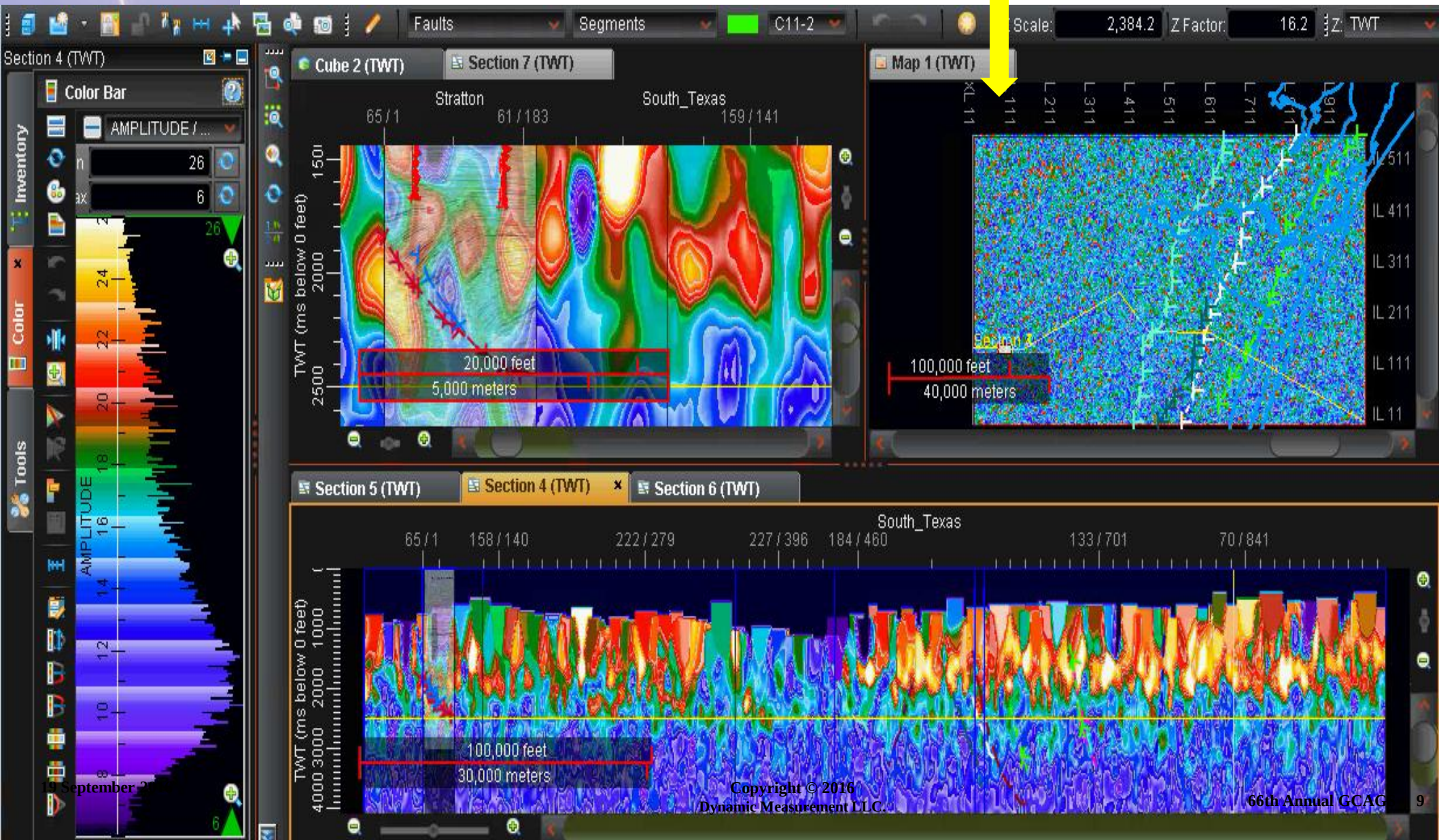
Published BEG Stratton Data to 2.3 sec.
(from Hardage,1986)

Stratton Seismic Sections

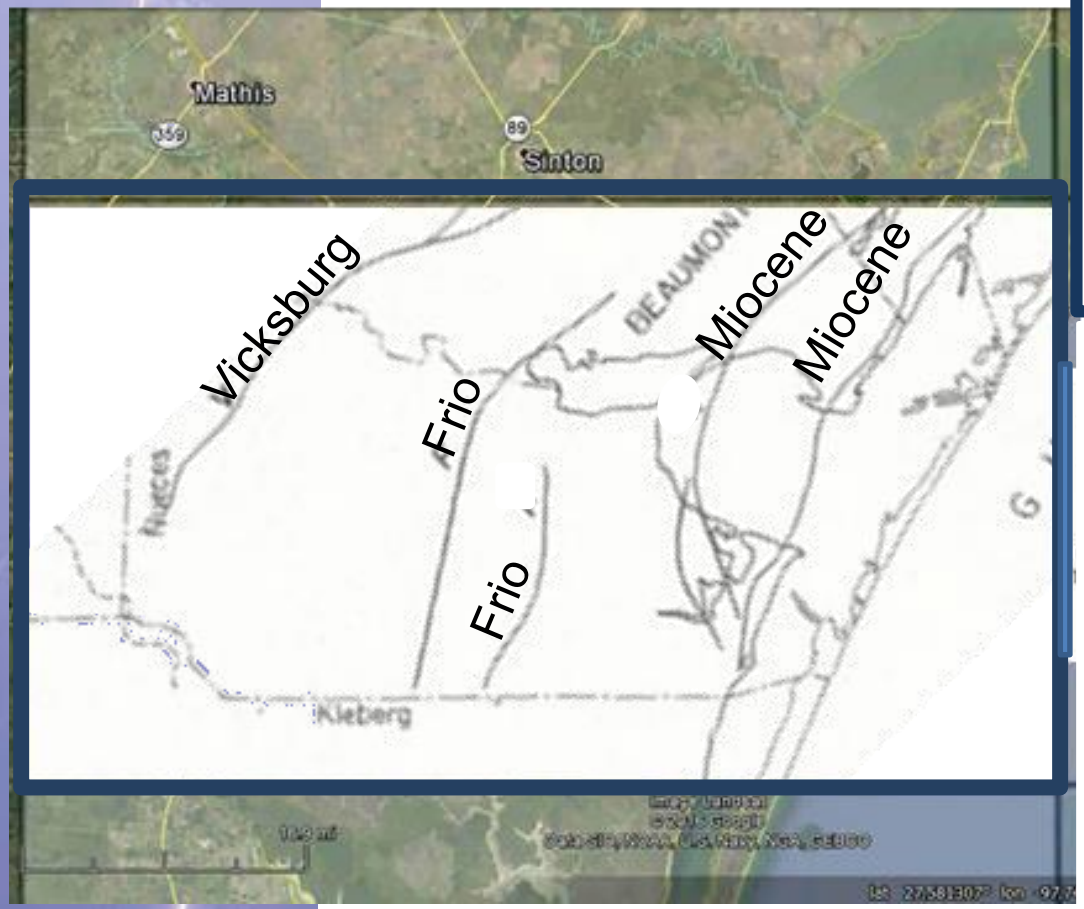


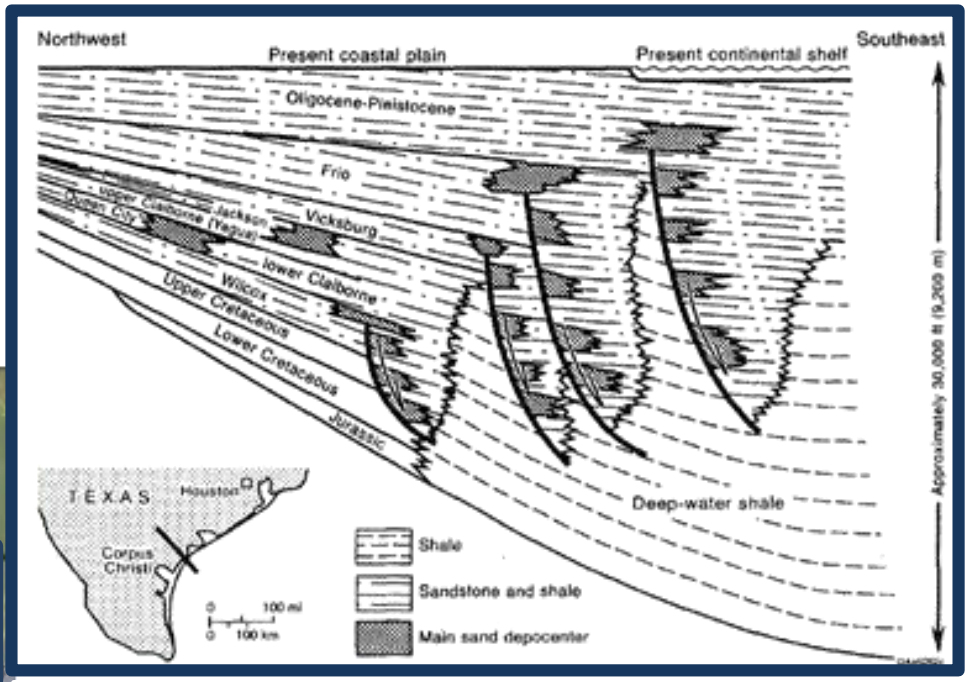


Apparent Resistivity extension of Ewing (1986) A-A' through Stratton seismic data



Geological Overview

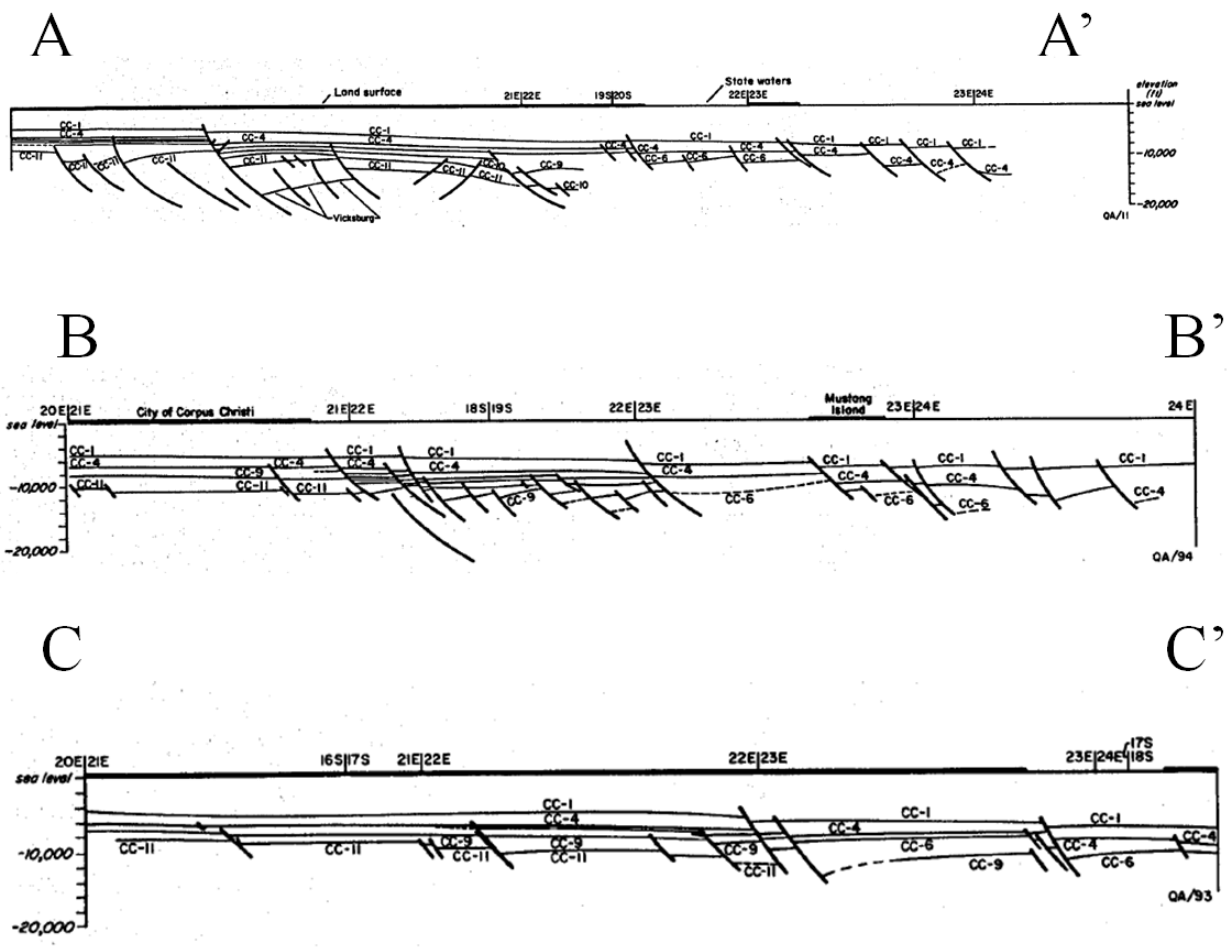




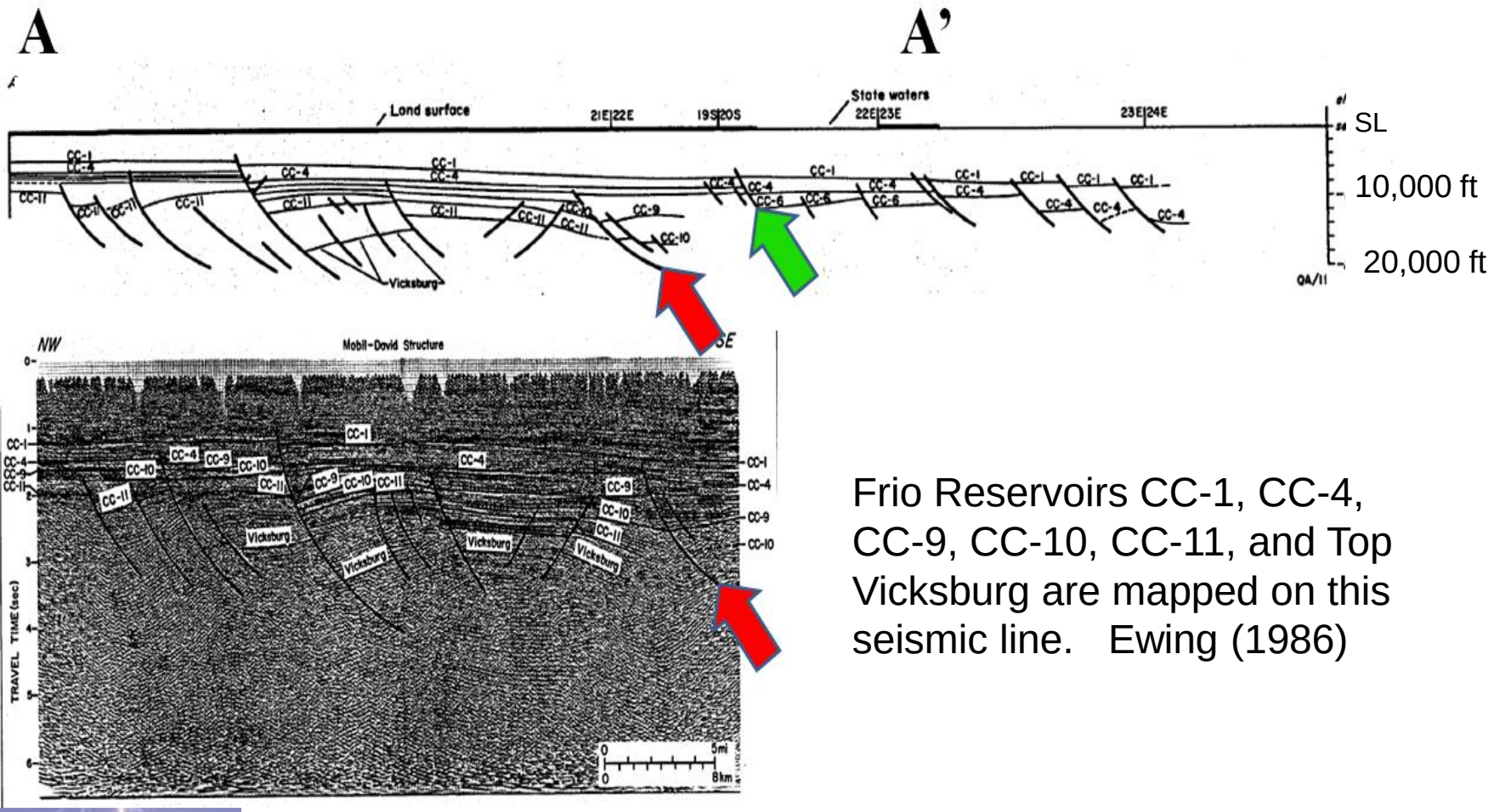
From Levey, et al,1994
Bebout and others,1982

After Solis, 1981

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

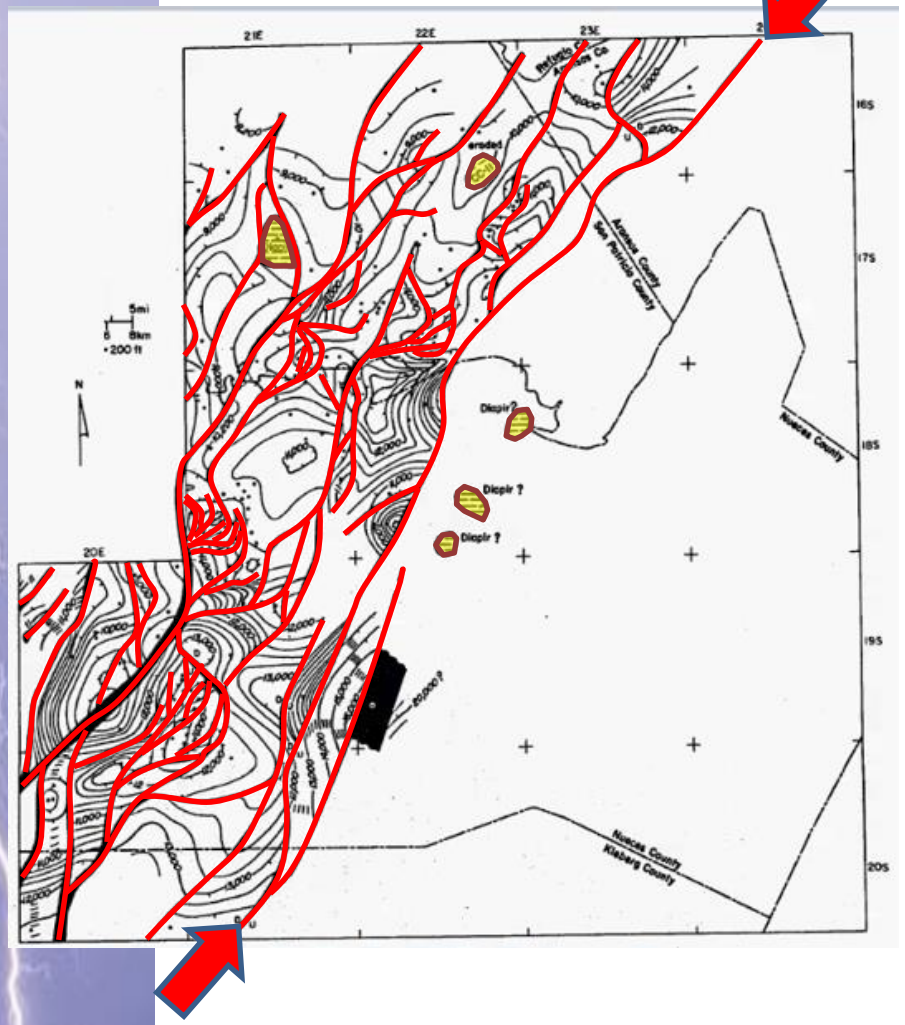


Ewing (1986) Fault A-A' and nearby seismic cross-section

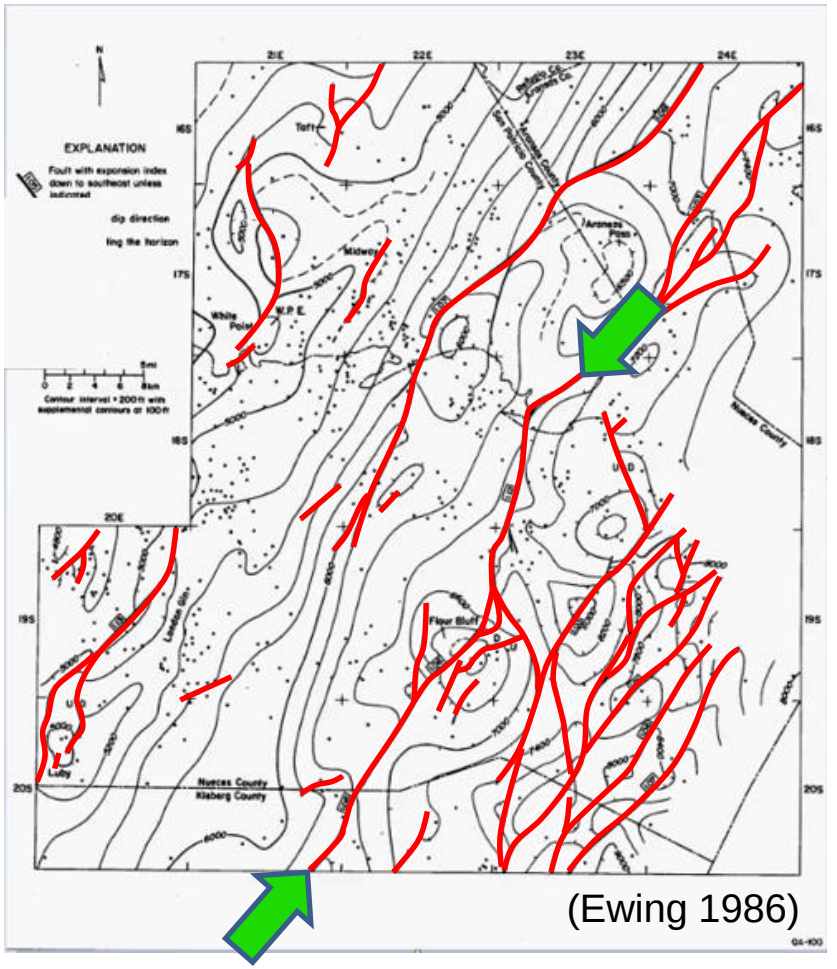


Frio Reservoirs CC-1, CC-4, CC-9, CC-10, CC-11, and Top Vicksburg are mapped on this seismic line. Ewing (1986)

Frio (C-11 horizon) Faults

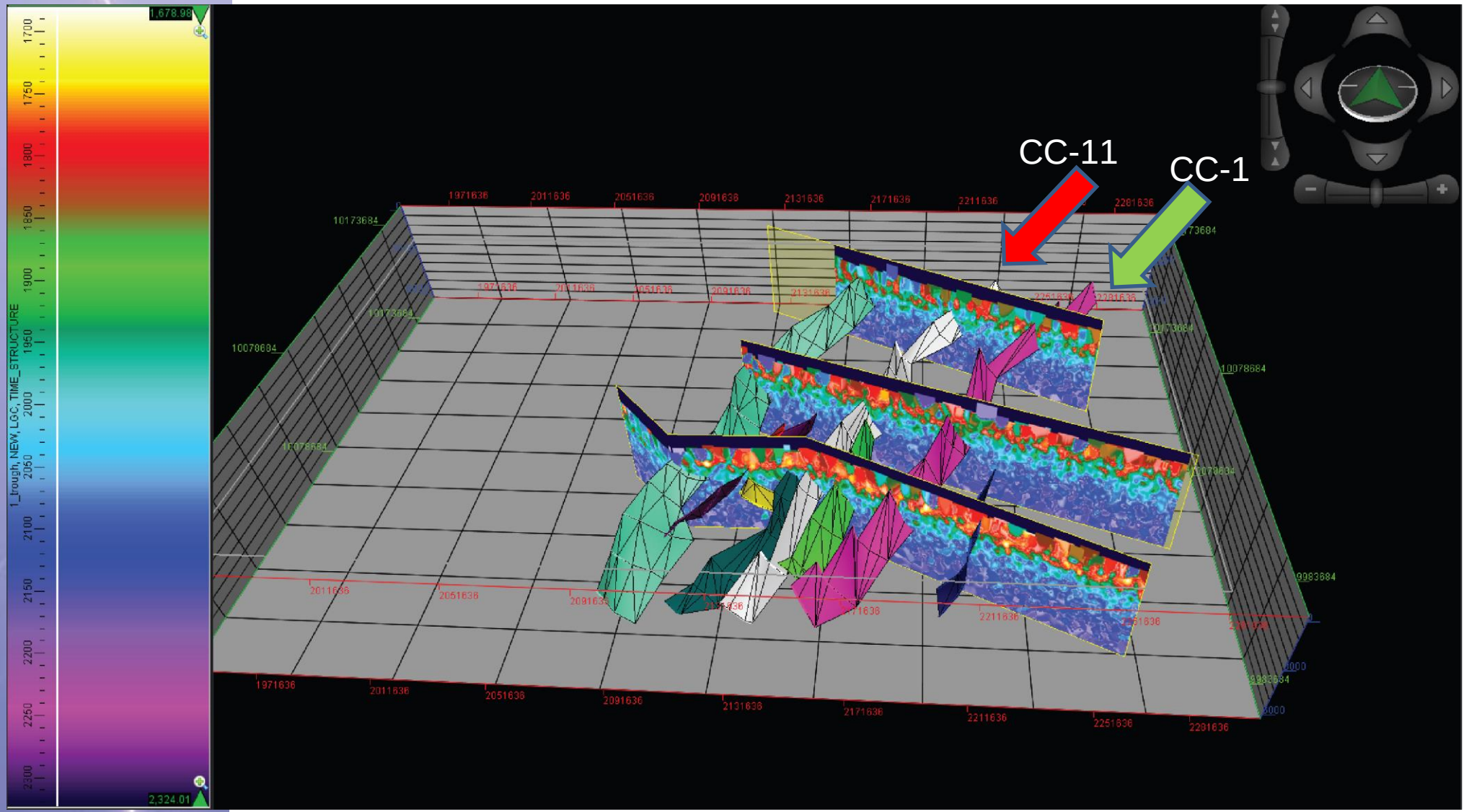


C-1 horizon Faults

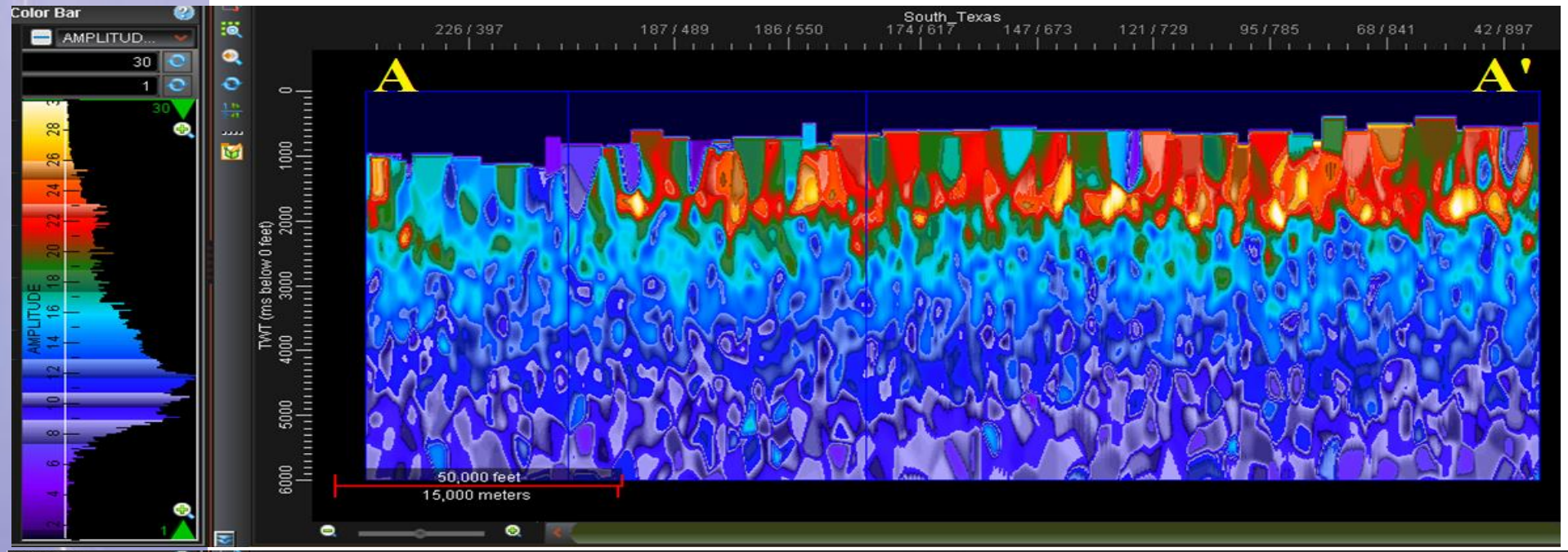


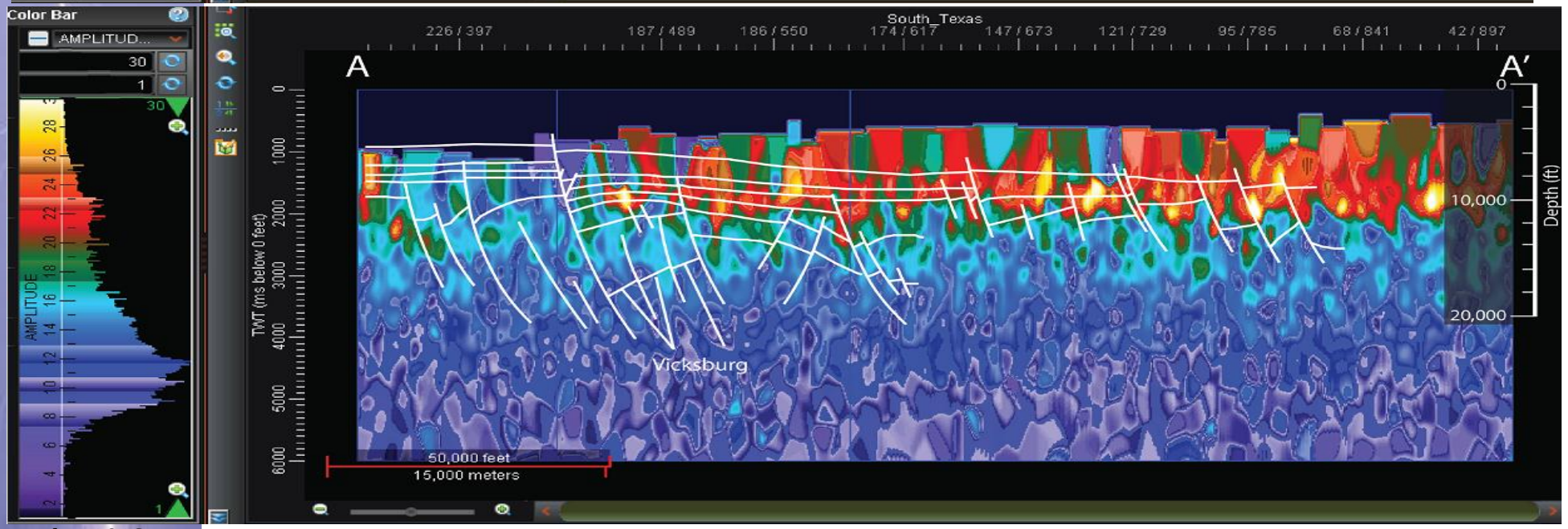
(Ewing 1986)

Lightning Derived Structural Framework

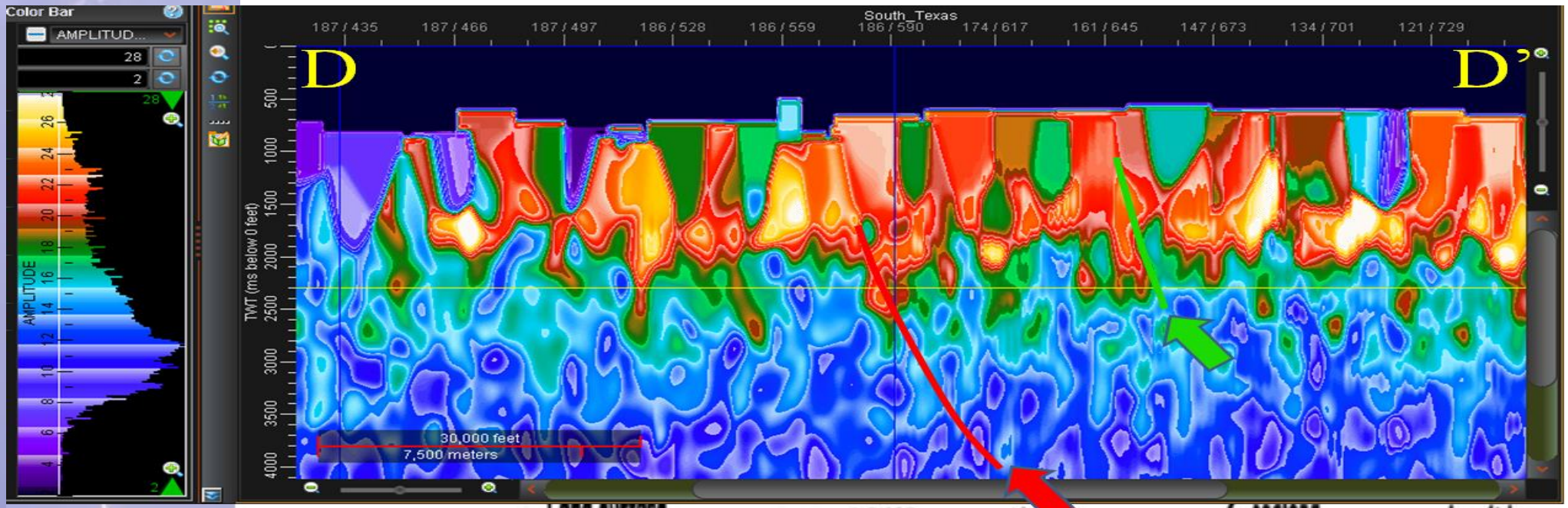


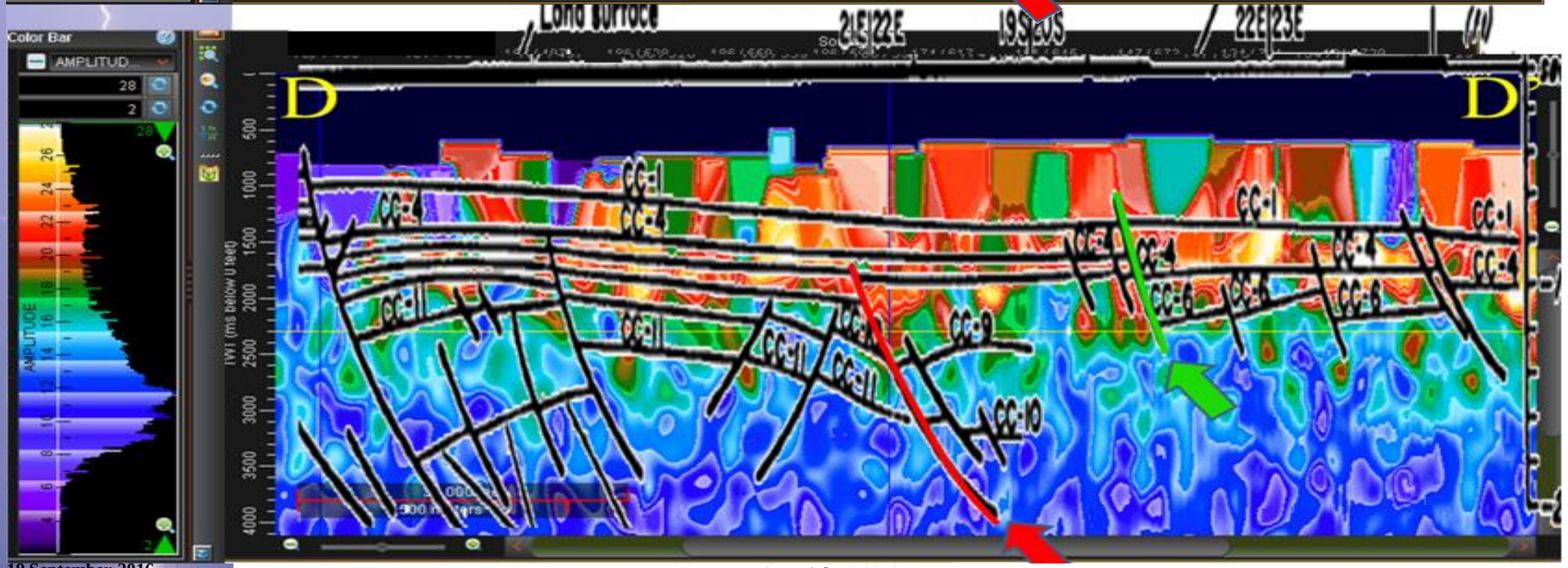
Ewing (1986) Fault Cross-Section A-A' Apparent Resistivity



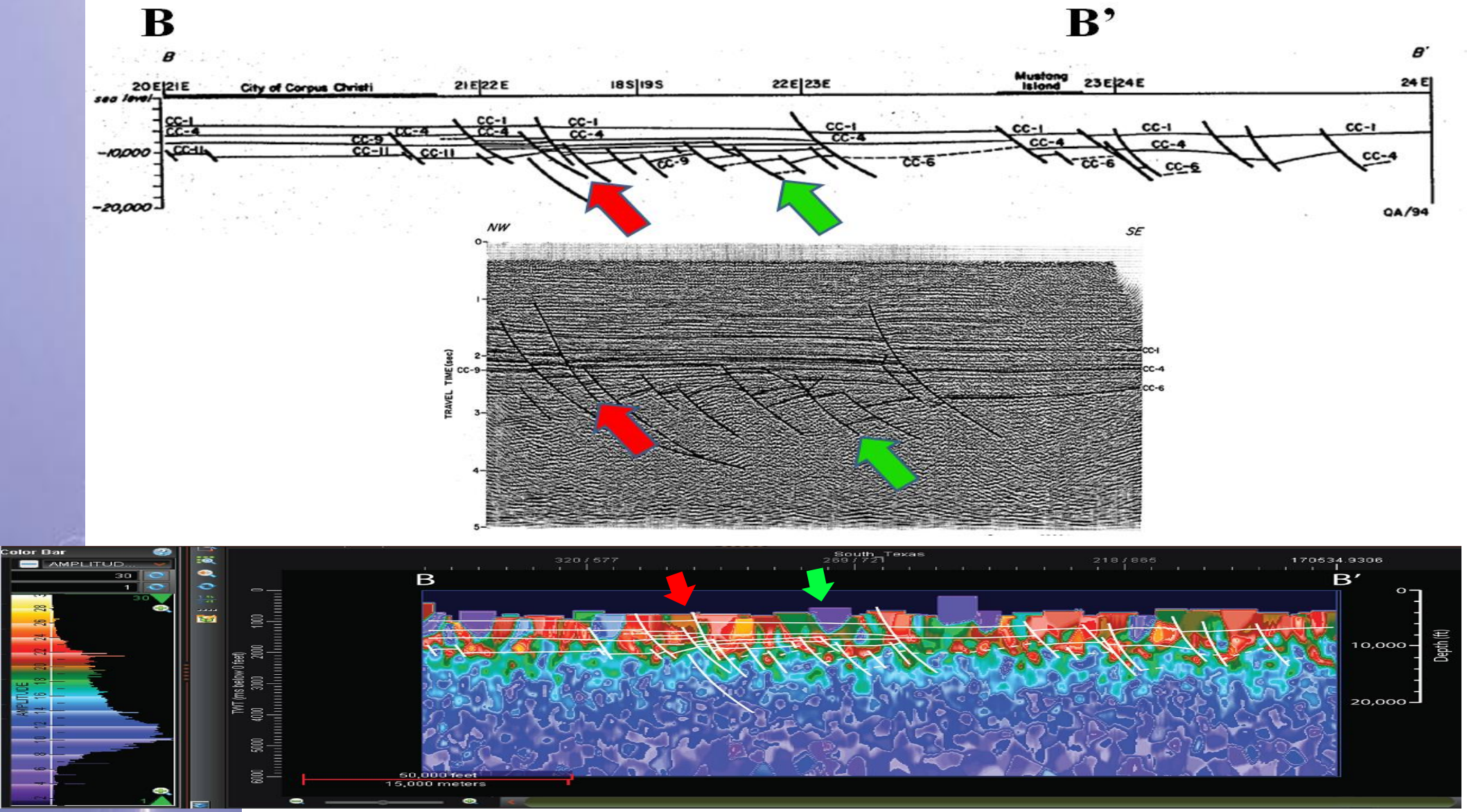


Zoom in on graben on west side of A-A’



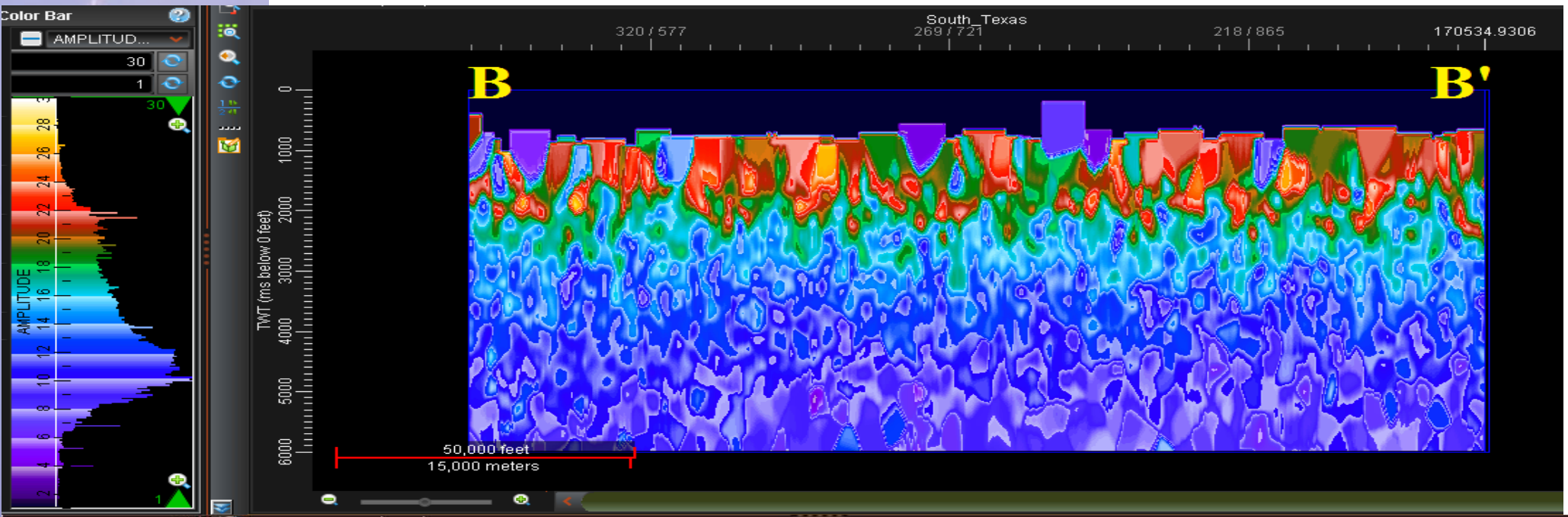


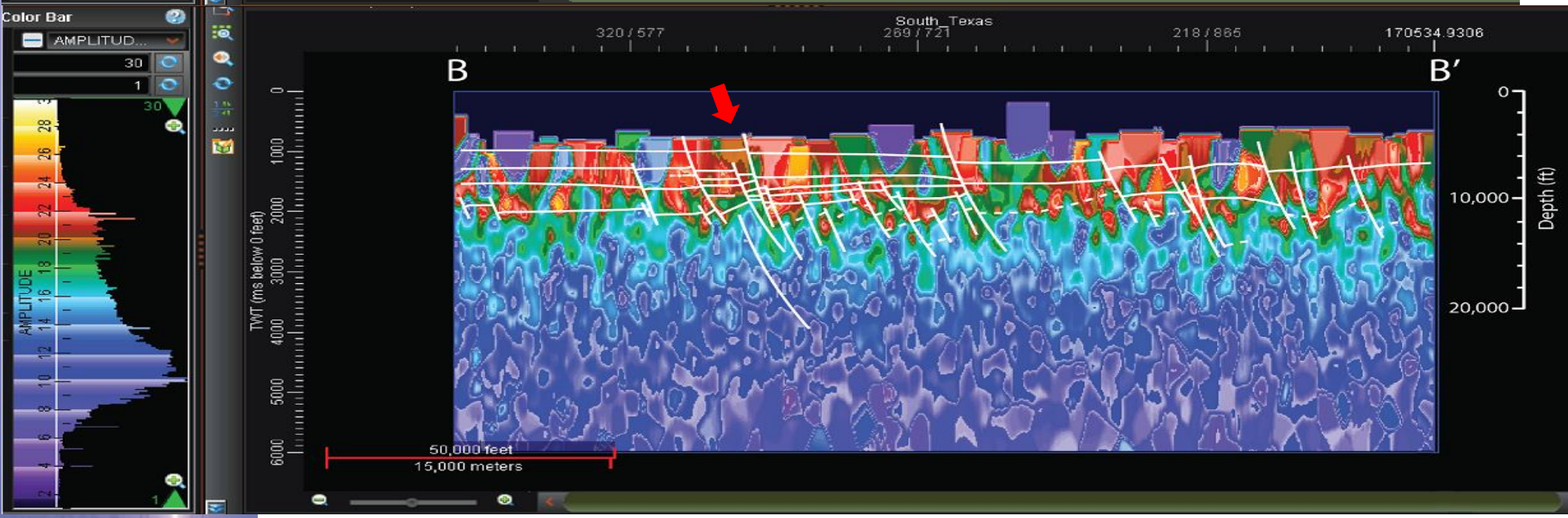
Ewing (1986) Fault B-B' and nearby seismic cross-section



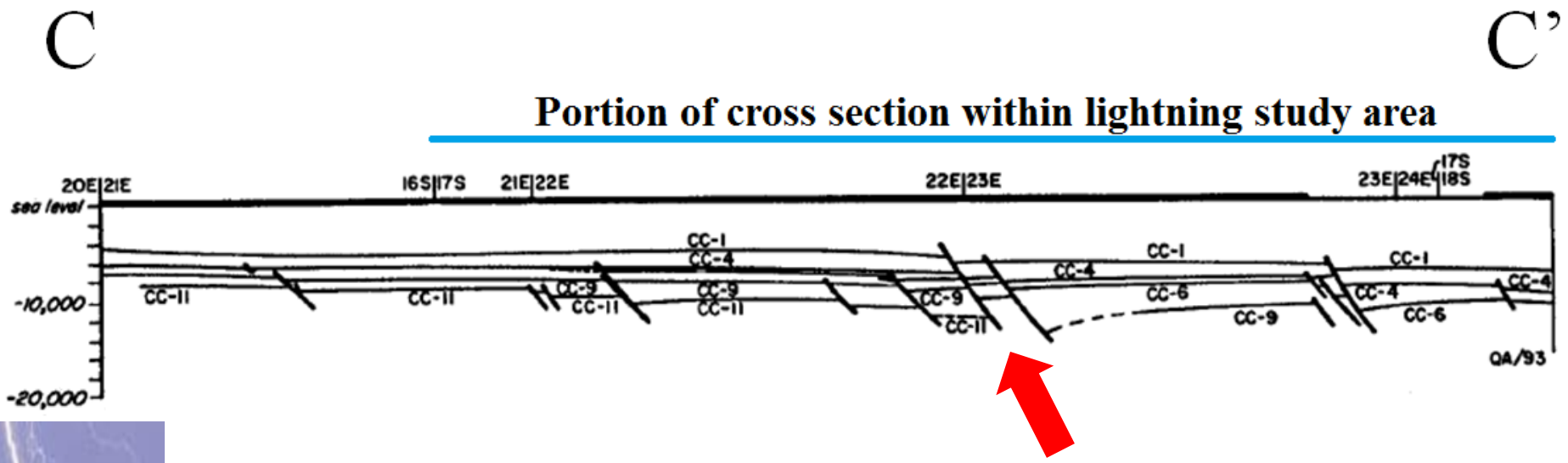
Apparent Resistivity Attribute with Ewing (1986) Cross Section Overlays B-B'

Ewing (1986) Fault Cross-Section B-B' Apparent Resistivity

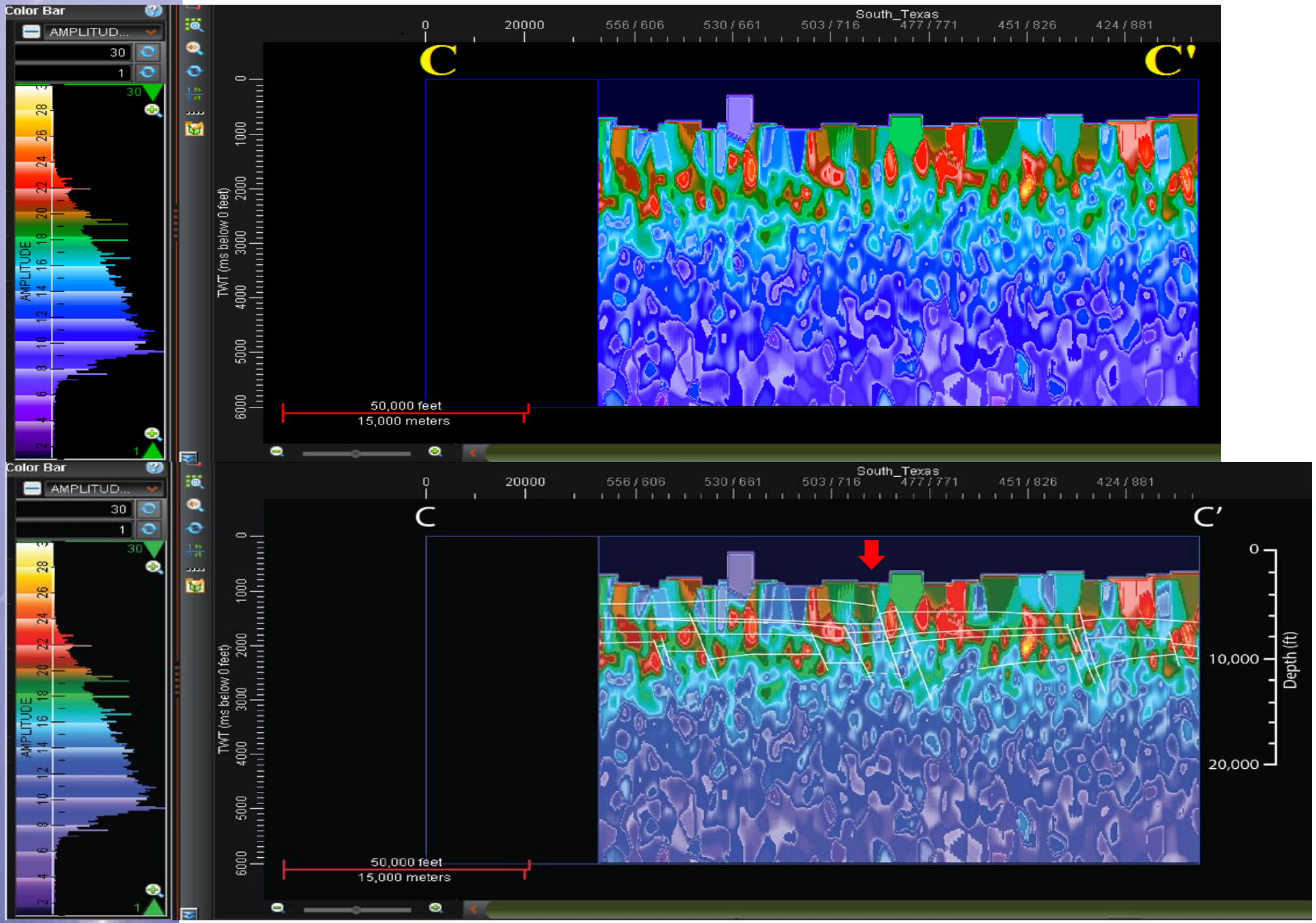




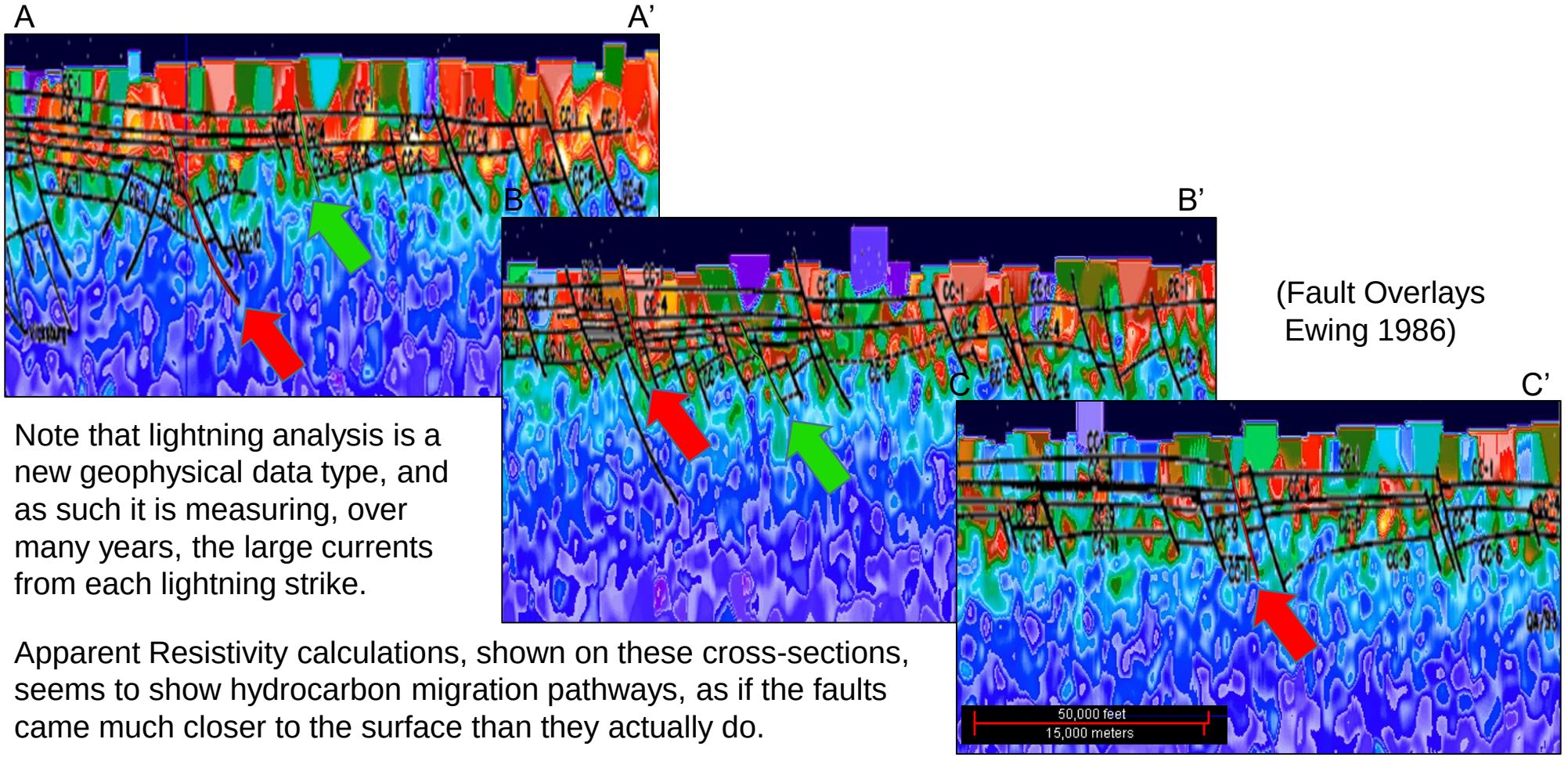
Ewing (1986) Fault Cross-Section C-C’



Ewing (1986) Fault Cross-Section C-C’ Apparent Resistivity



Red & Green Fault on A-A', B-B', & C-C'



(Fault Overlays Ewing 1986)

Note that lightning analysis is a new geophysical data type, and as such it is measuring, over many years, the large currents from each lightning strike.

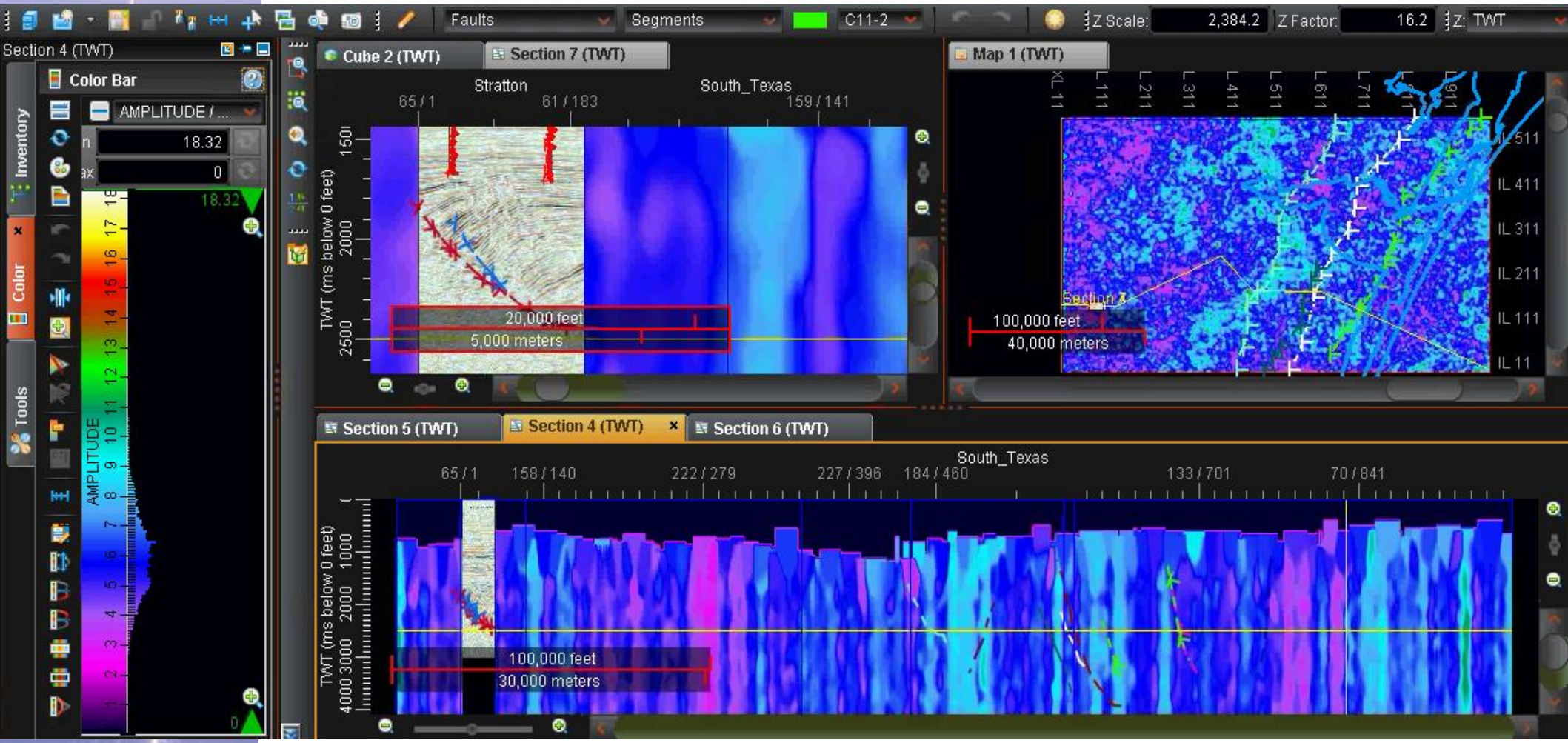
Apparent Resistivity calculations, shown on these cross-sections, seems to show hydrocarbon migration pathways, as if the faults came much closer to the surface than they actually do.

Attribute Scales

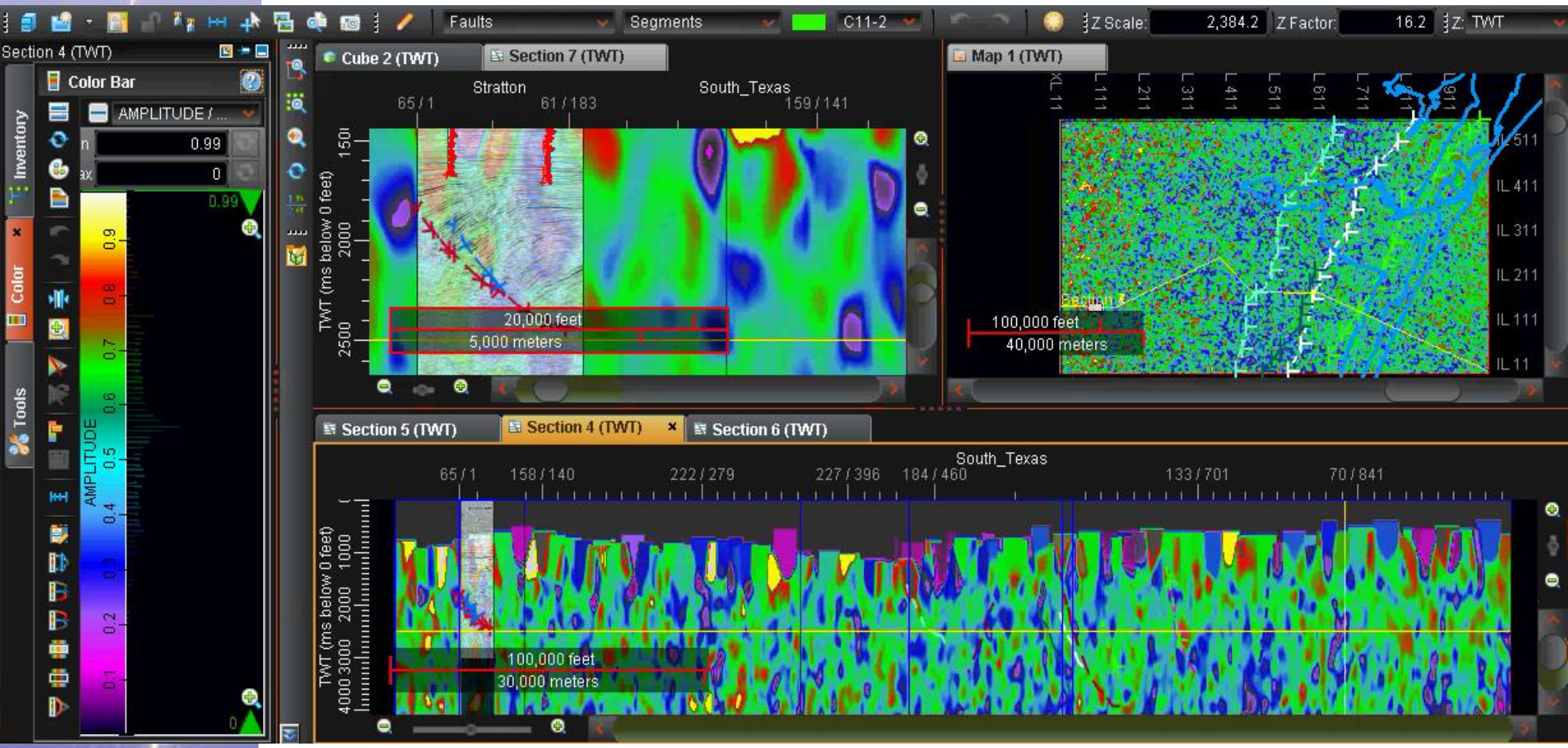
1. Density (Strikes per sq km, per year). Wholly digital data; duration and or area can be any desired range of Density time values.
2. Day-of-Year (Decimal fraction of calendar year; range is from 0.0 on Jan. 1st to 1.0 at midnight of the following Dec. 31st.
3. Energy ([pc * (rt + pz)/2] milliampere-seconds)
4. Frequency (kilohertz)
5. Moon Local Longitude (degrees [-180 to 180])
6. Moon Phase (degrees [0-360])
7. Peak-to-Zero (microseconds)
8. Peak Current Absolute (kiloamperes)
9. Apparent Permittivity (microfarads per meter)
10. Apparent Resistivity (ohm-meters)
11. Rise-Time (microseconds)
12. Spike (map position of strike, or calculated volume position of strike)
13. Sun Local Longitude (degrees [-180 to 180])
14. Symmetry (% [<50: rt<pz; 50: rt=pz; >50: rt>pz])
15. Tidal Gravity (microgals [+- relative to long term mean])
16. Tidal Gradient (first derivative of Tide)
17. Tide (fraction of tidal range [-1.0: low spring tide; 0.0: mean tide; 1.0: high spring tide])
18. Total Wavelet Time (microseconds)

Temporal variations of any of the above attributes (sorting data from time 1 to time 2)

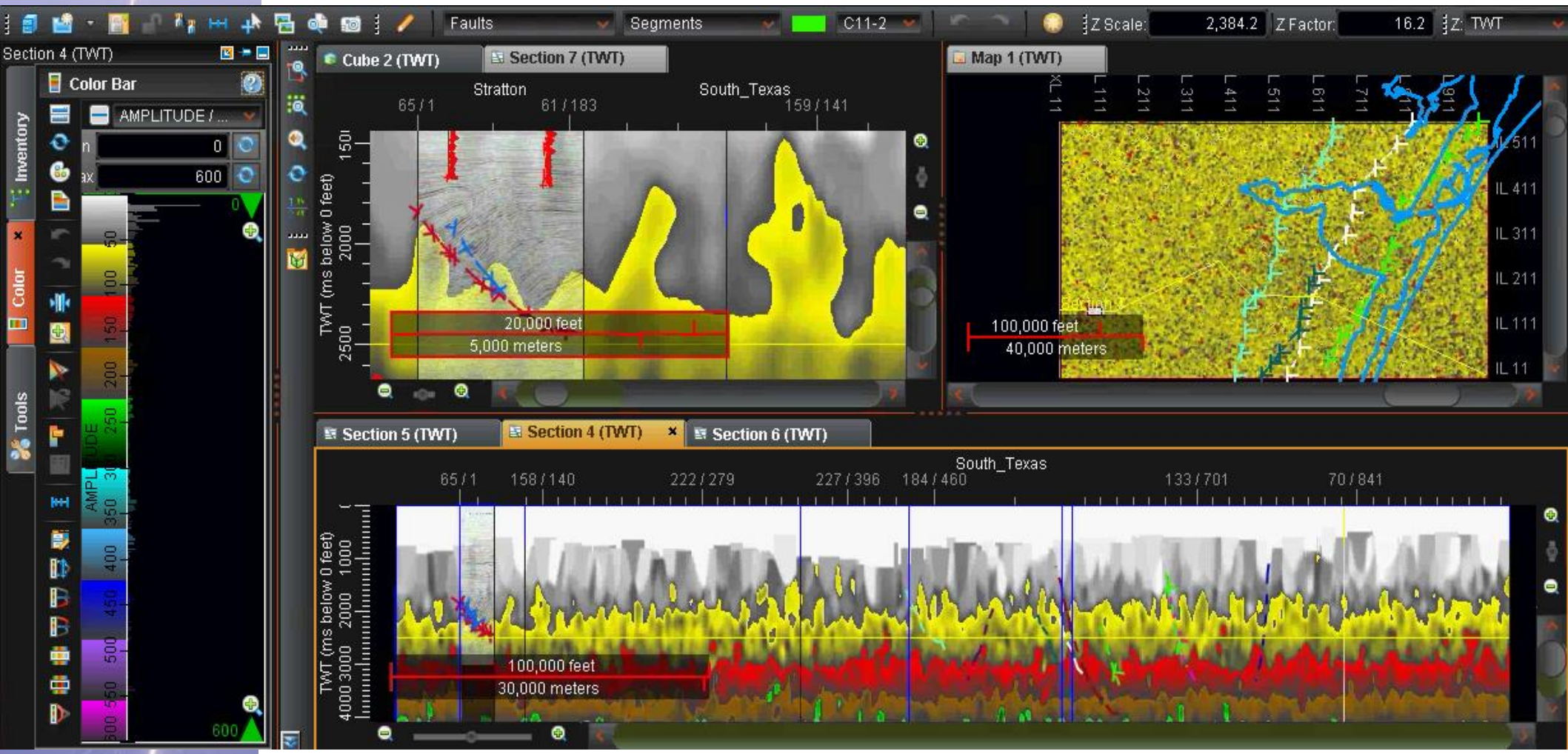
Lightning Attribute - Density



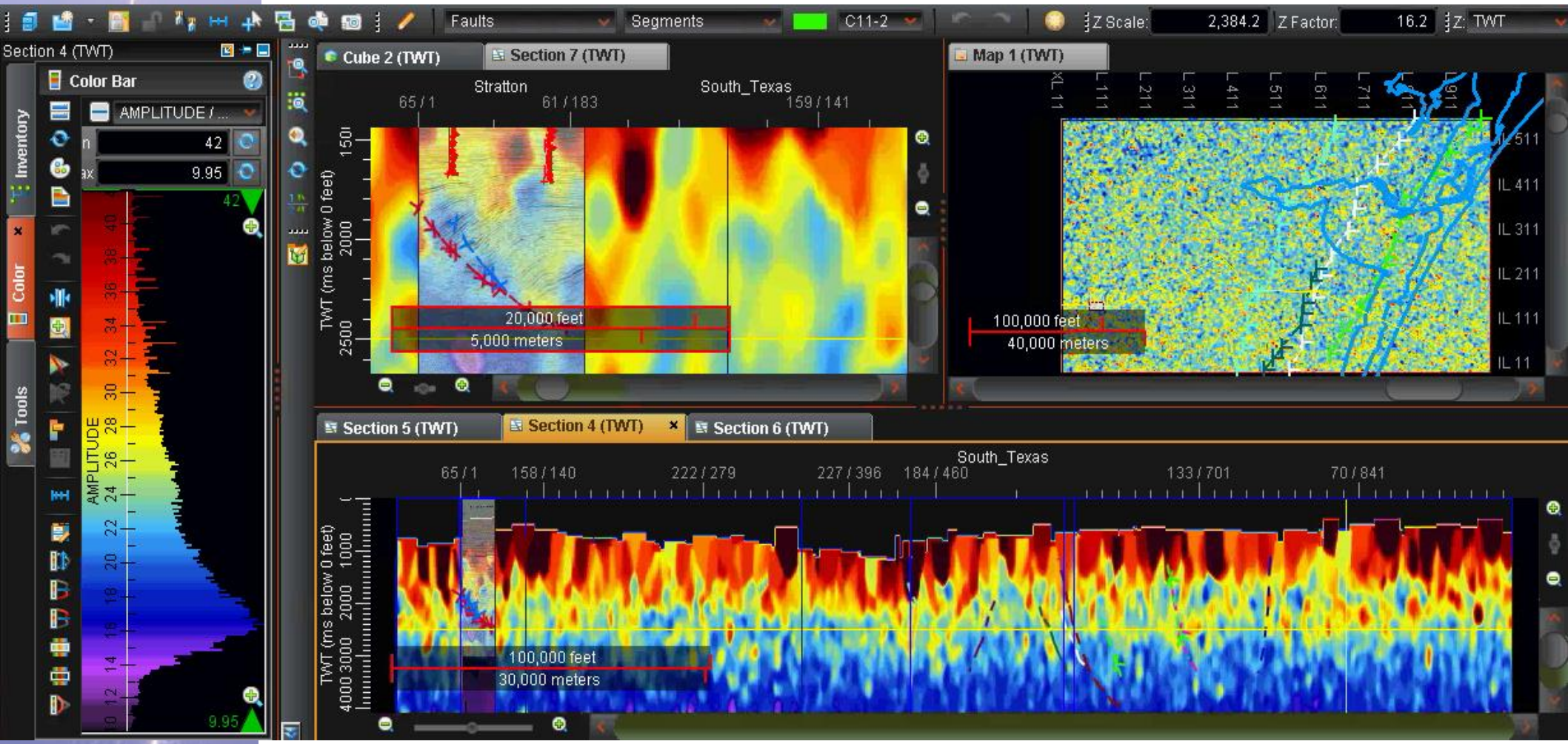
Lightning Attribute - Day of Year



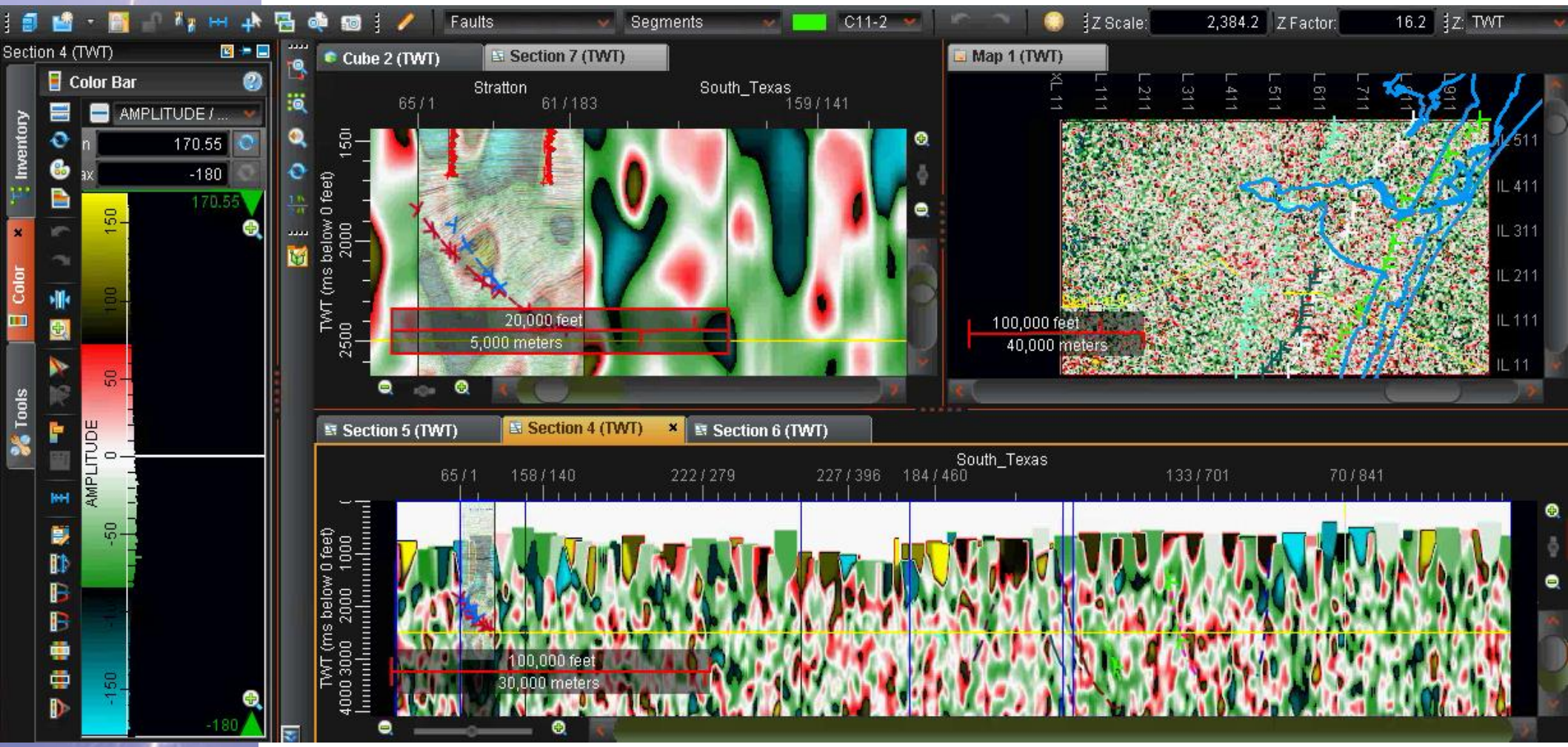
Lightning Attribute - Energy



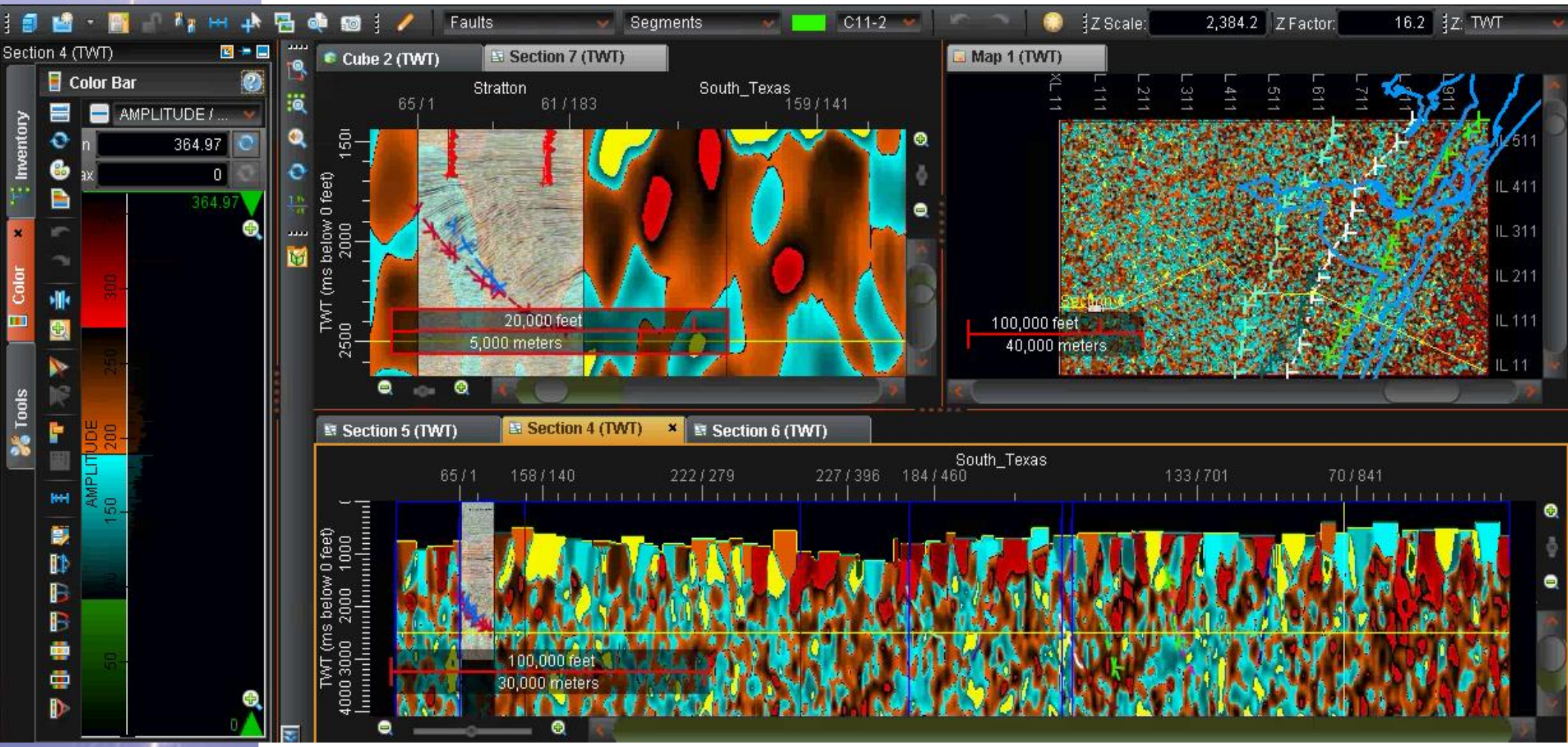
Lightning Attribute - Frequency



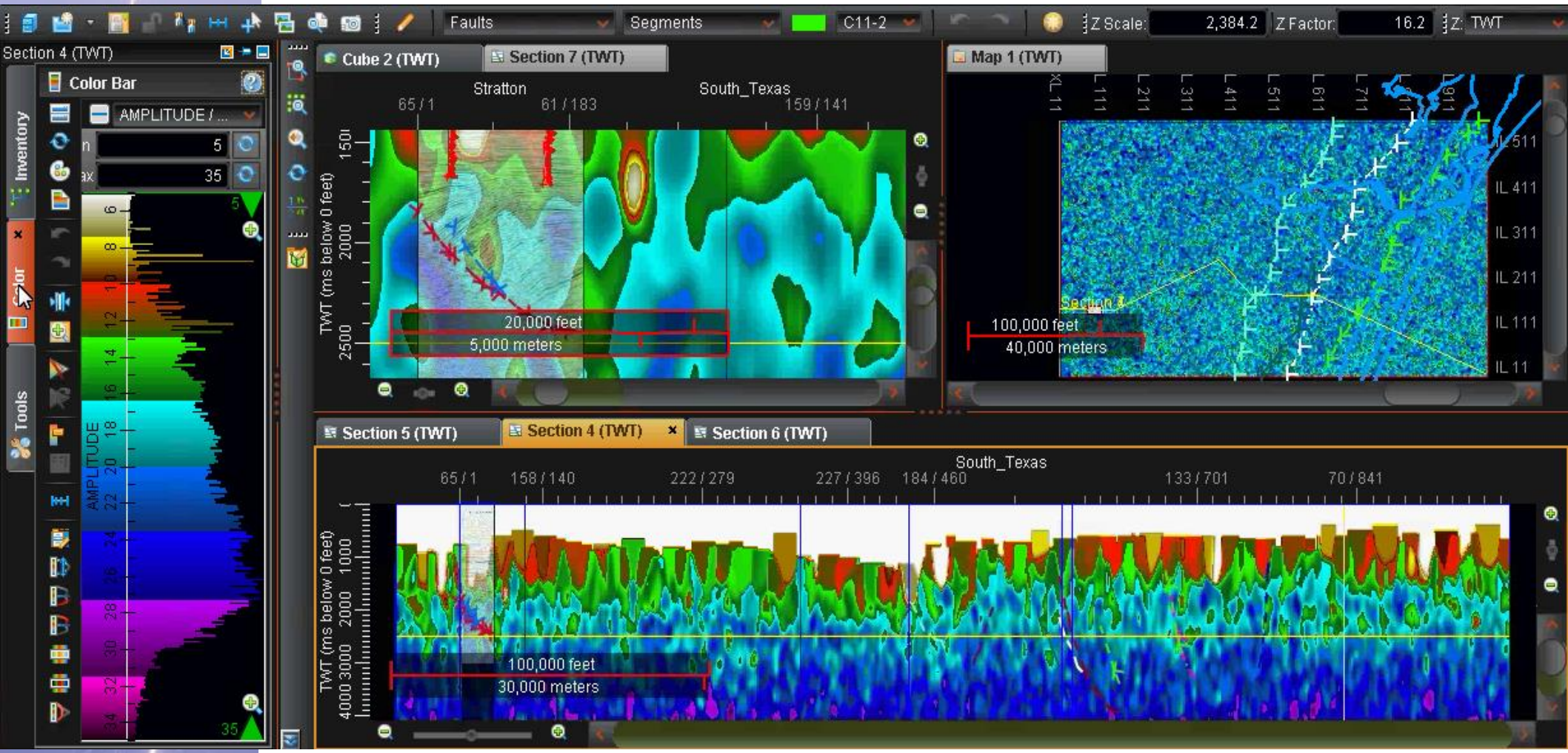
Lightning Attribute - Moon Local Longitude



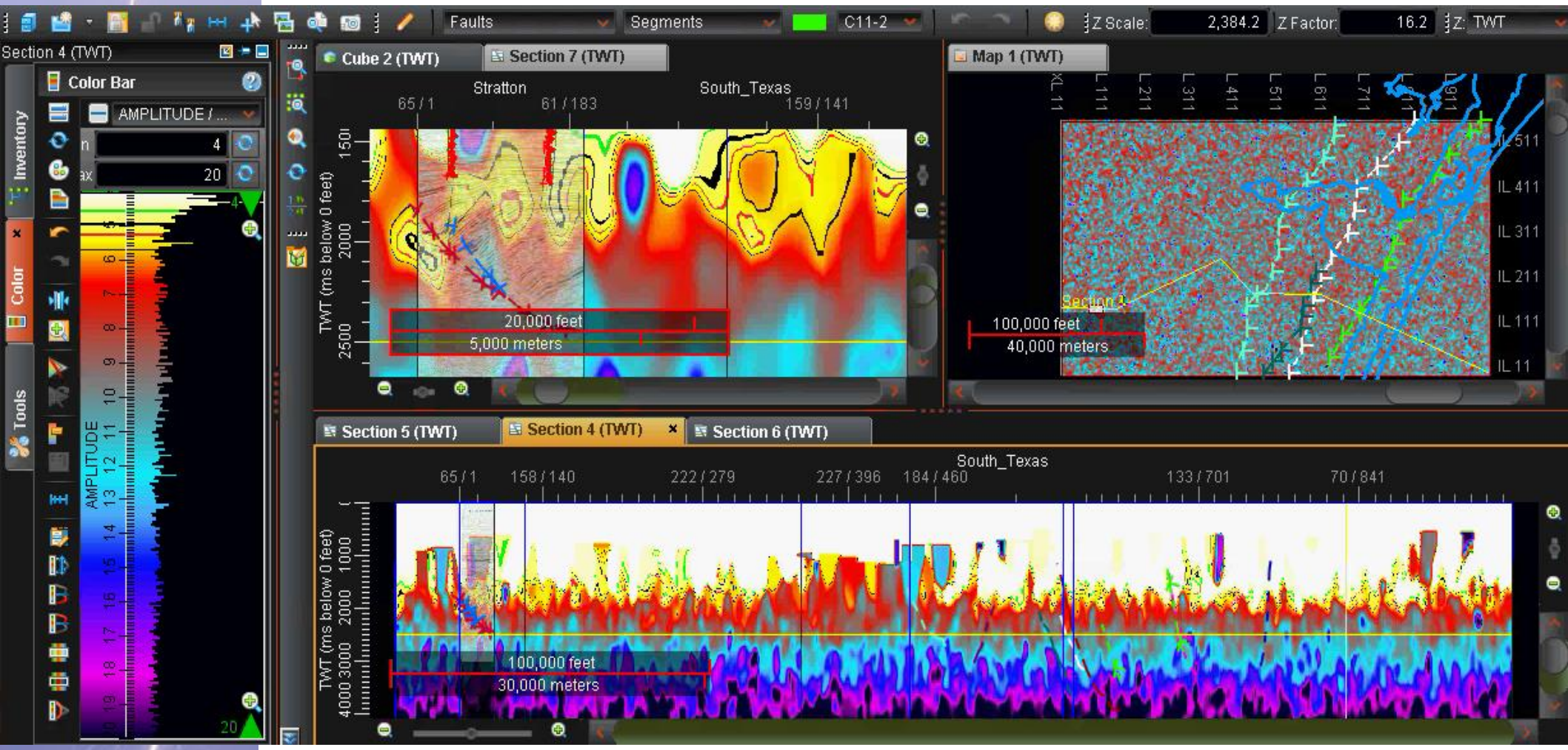
Lightning Attribute - Moon Phase



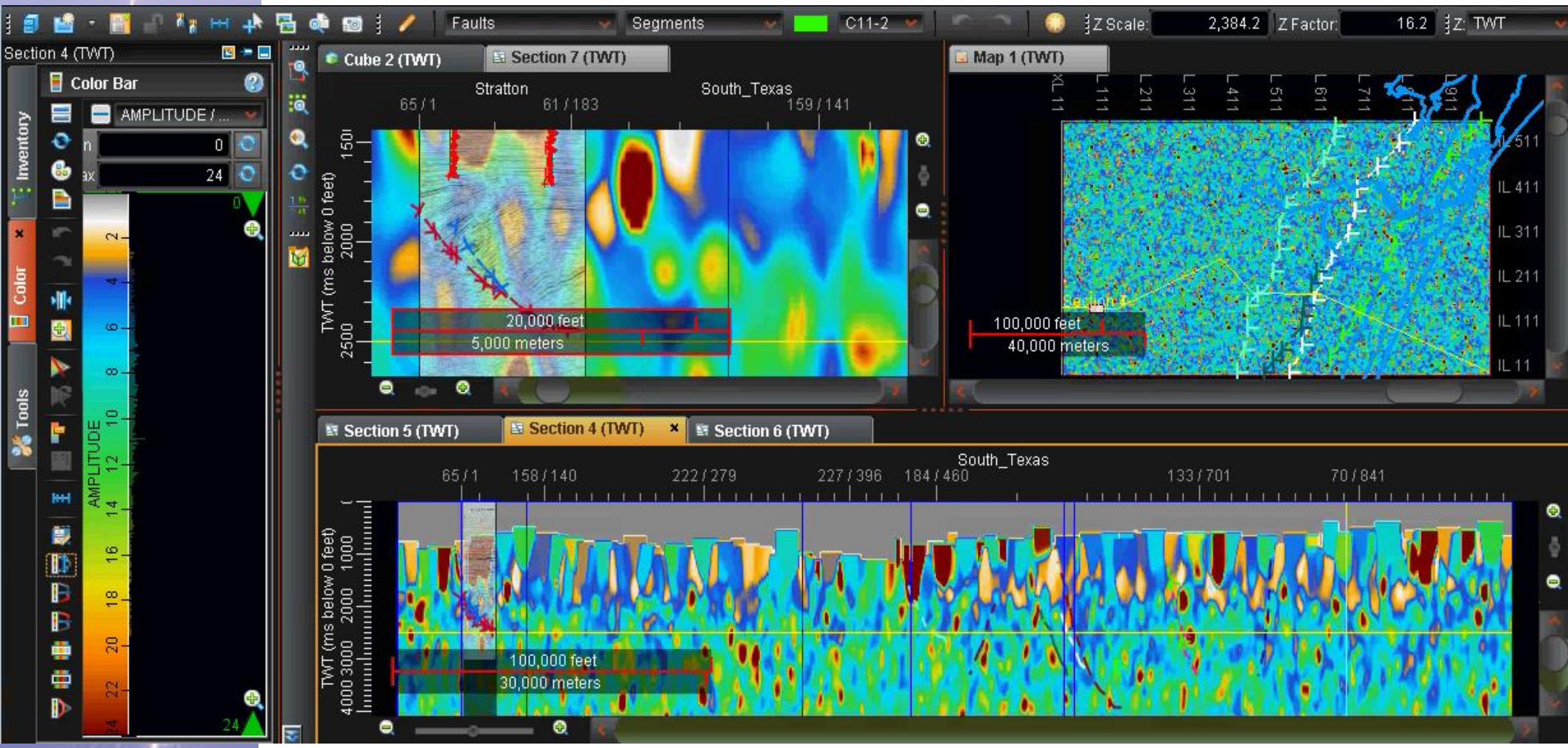
Lightning Attribute - Peak to Zero



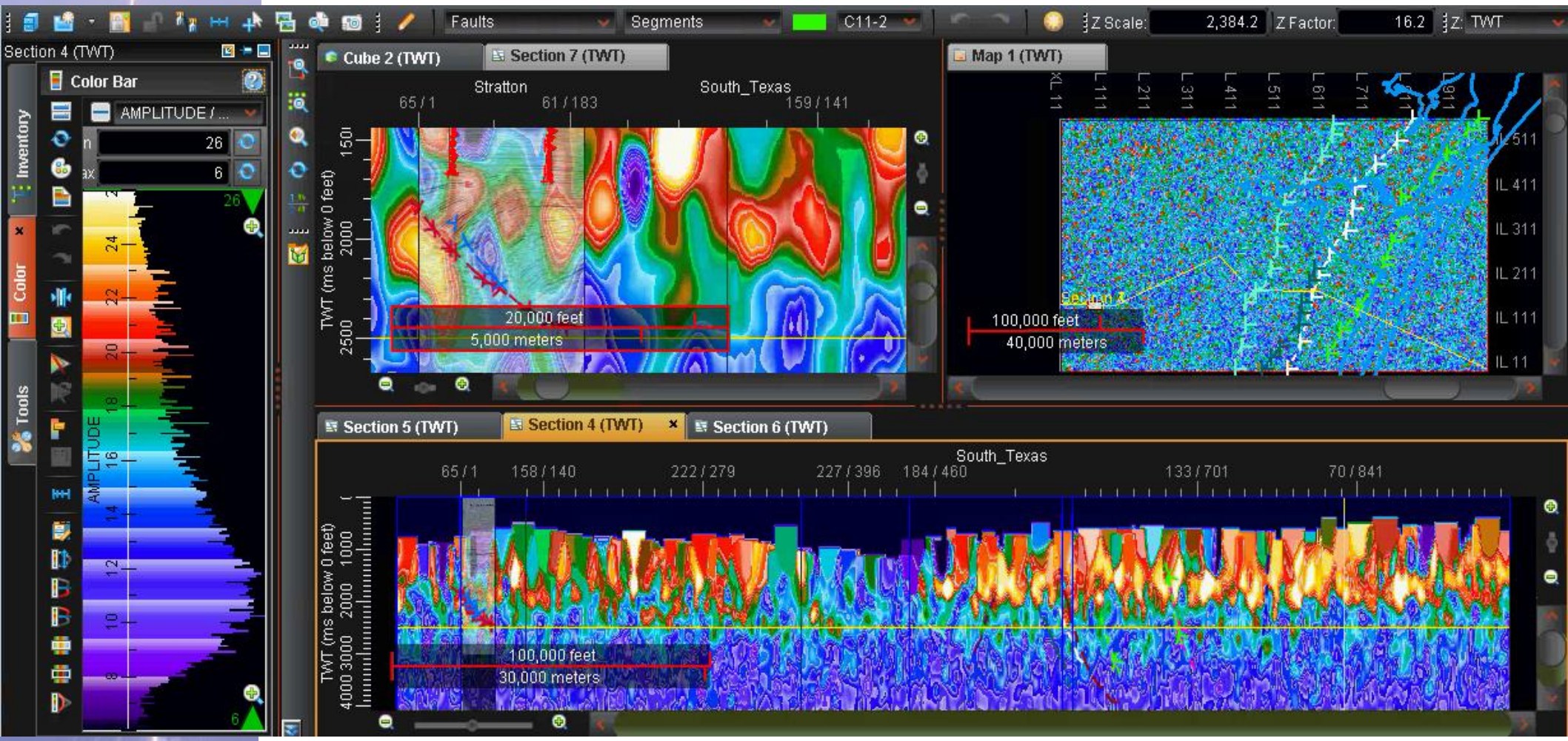
Lightning Attribute - Peak Current



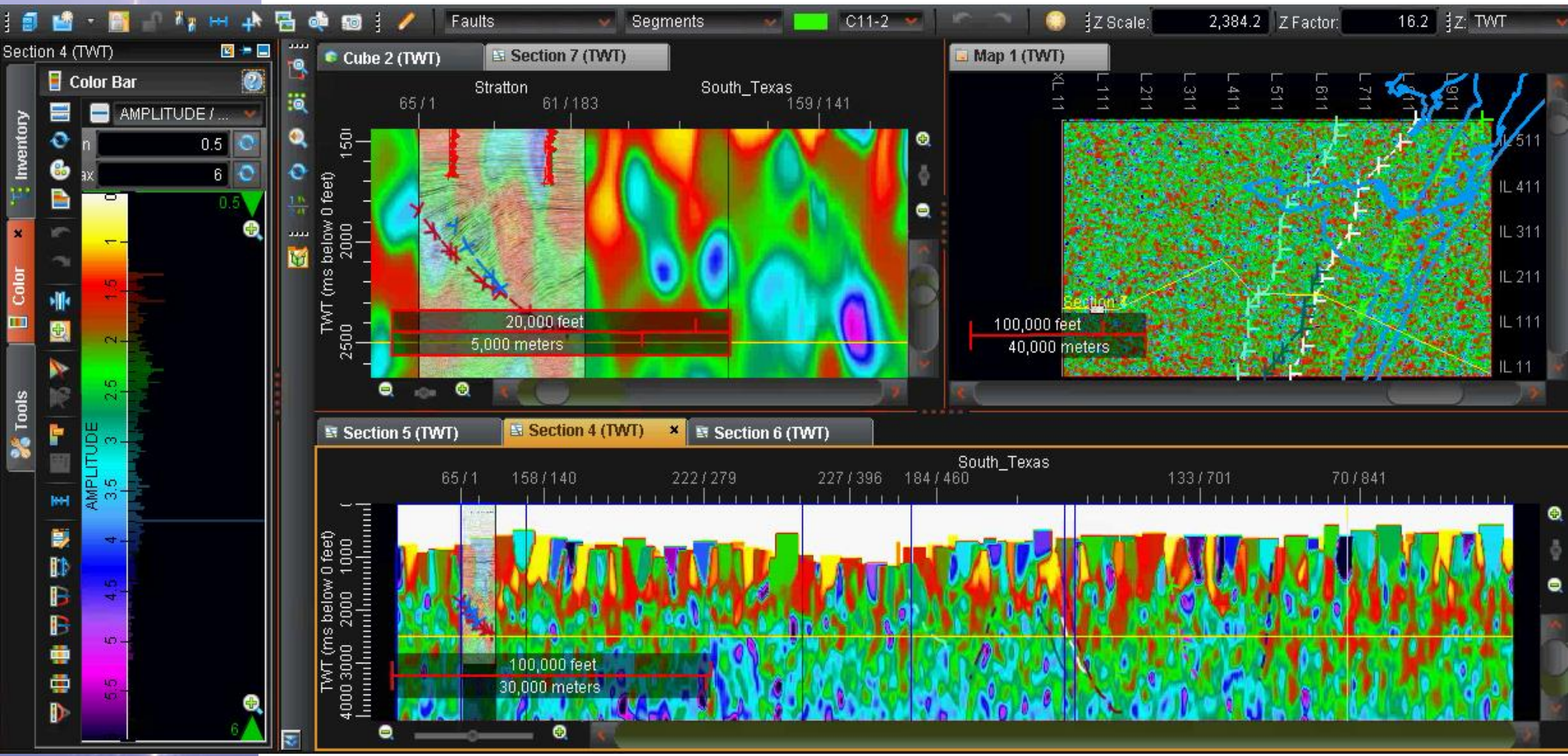
Lightning Attribute - Apparent Permittivity



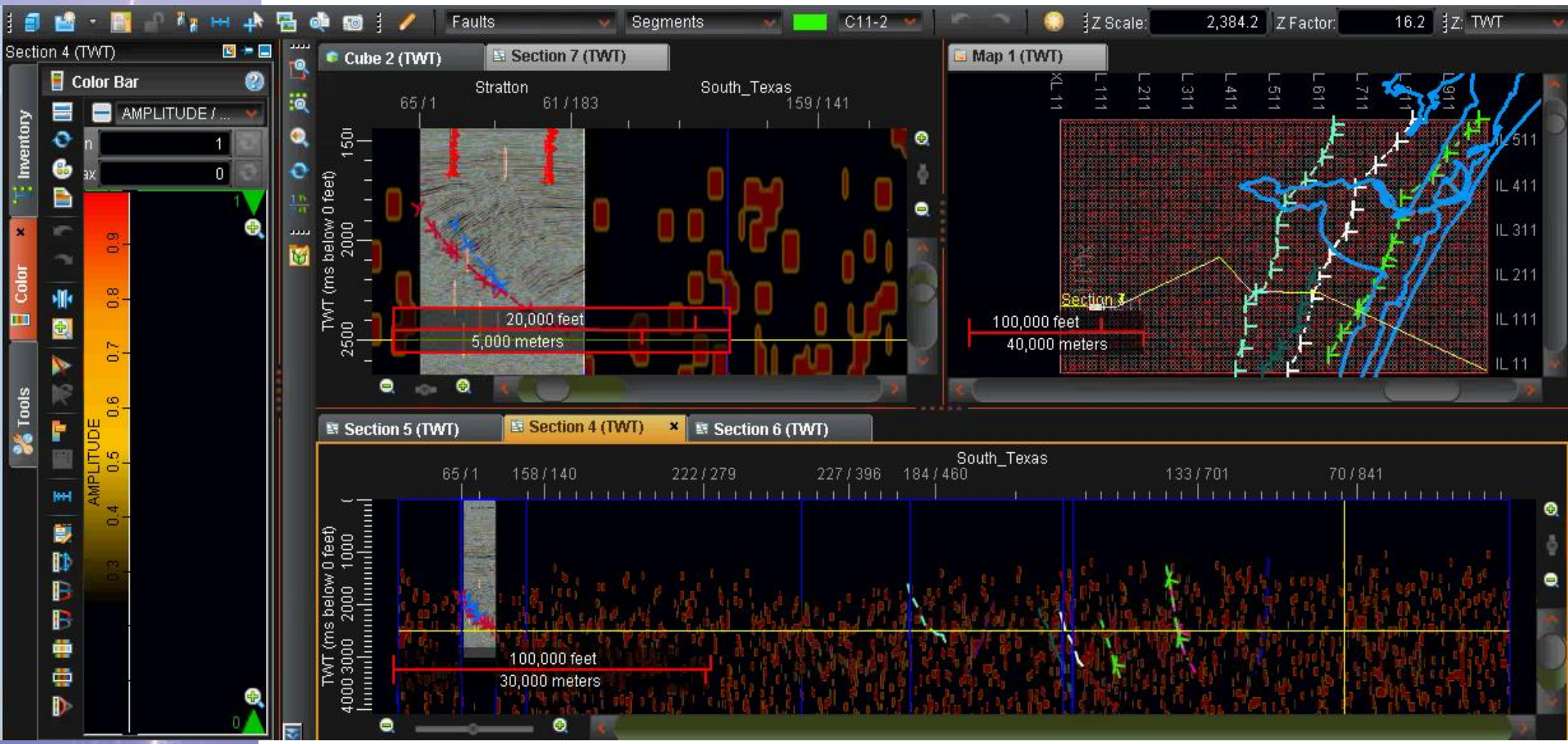
Lightning Attribute - Apparent Resistivity



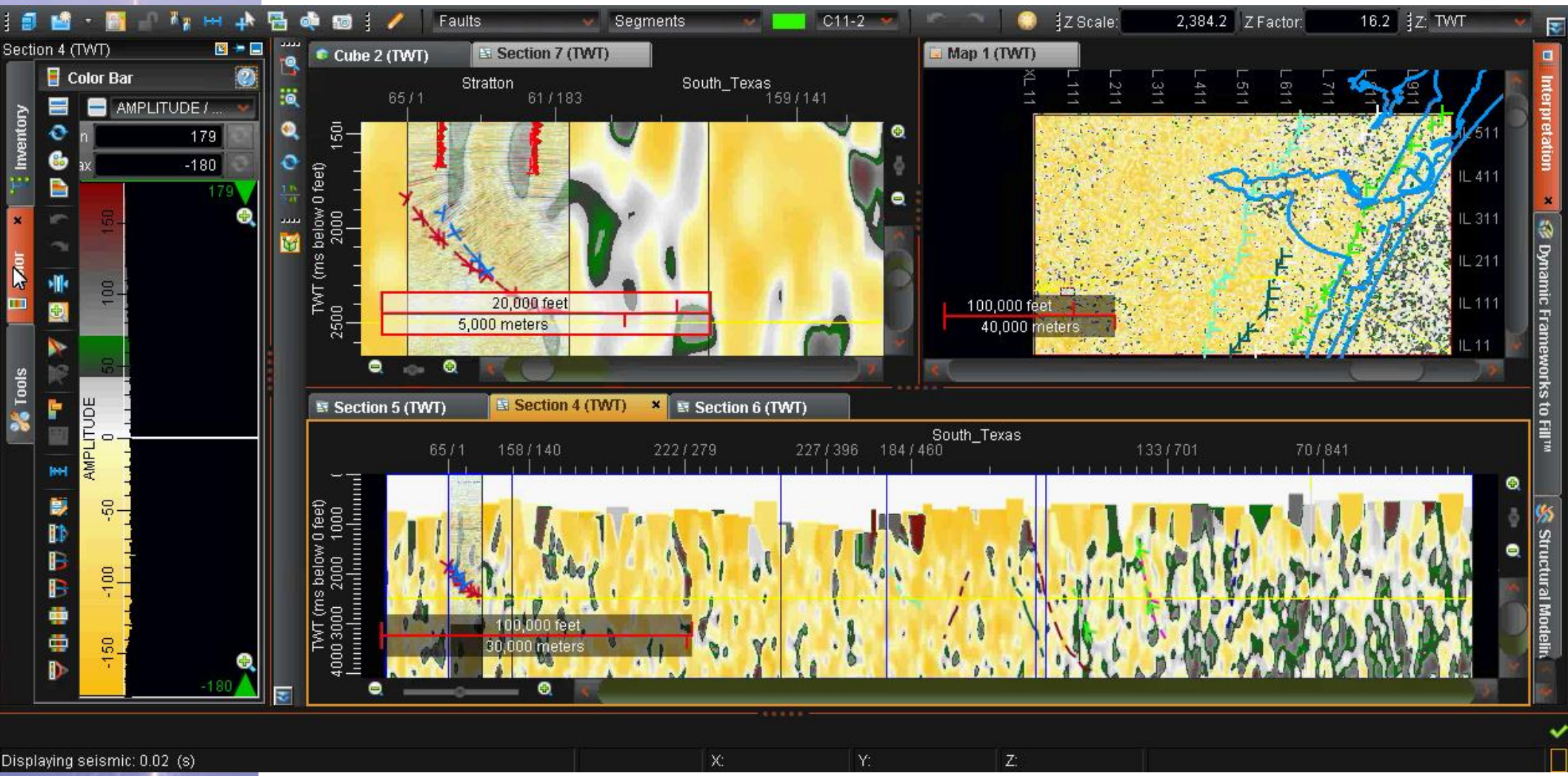
Lightning Attribute - Rise Time



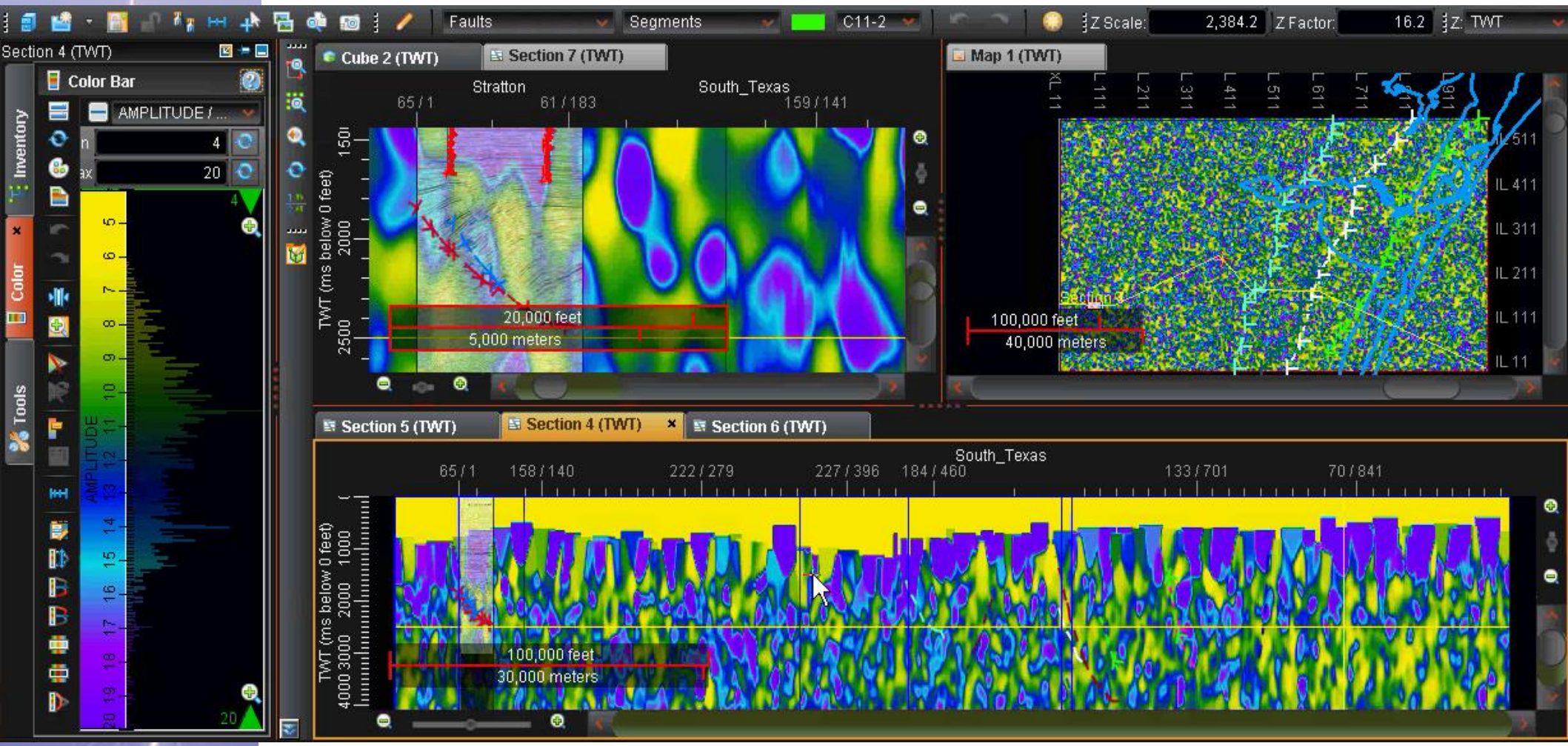
Lightning Attribute - Spike



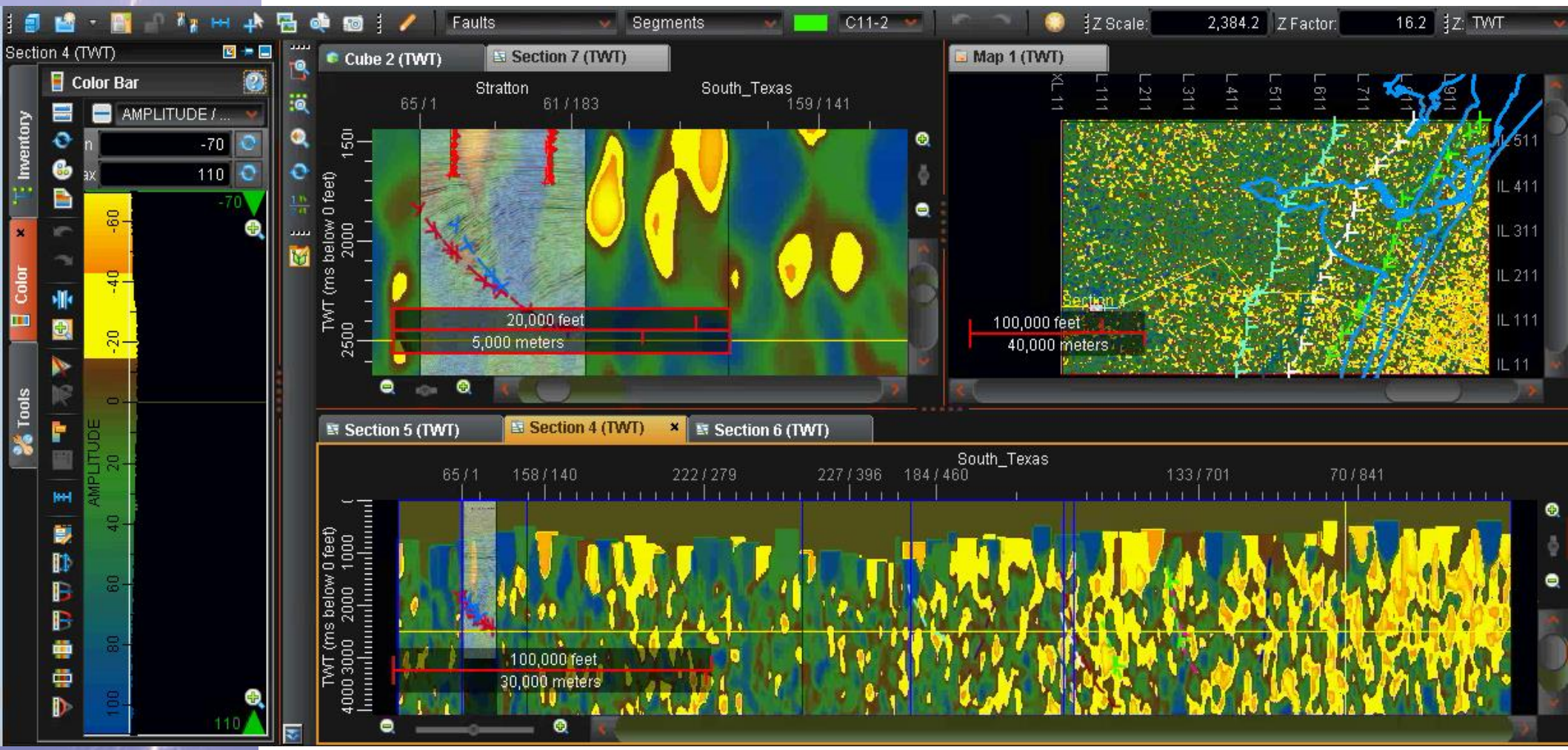
Lightning Attribute - Sun Local Longitude



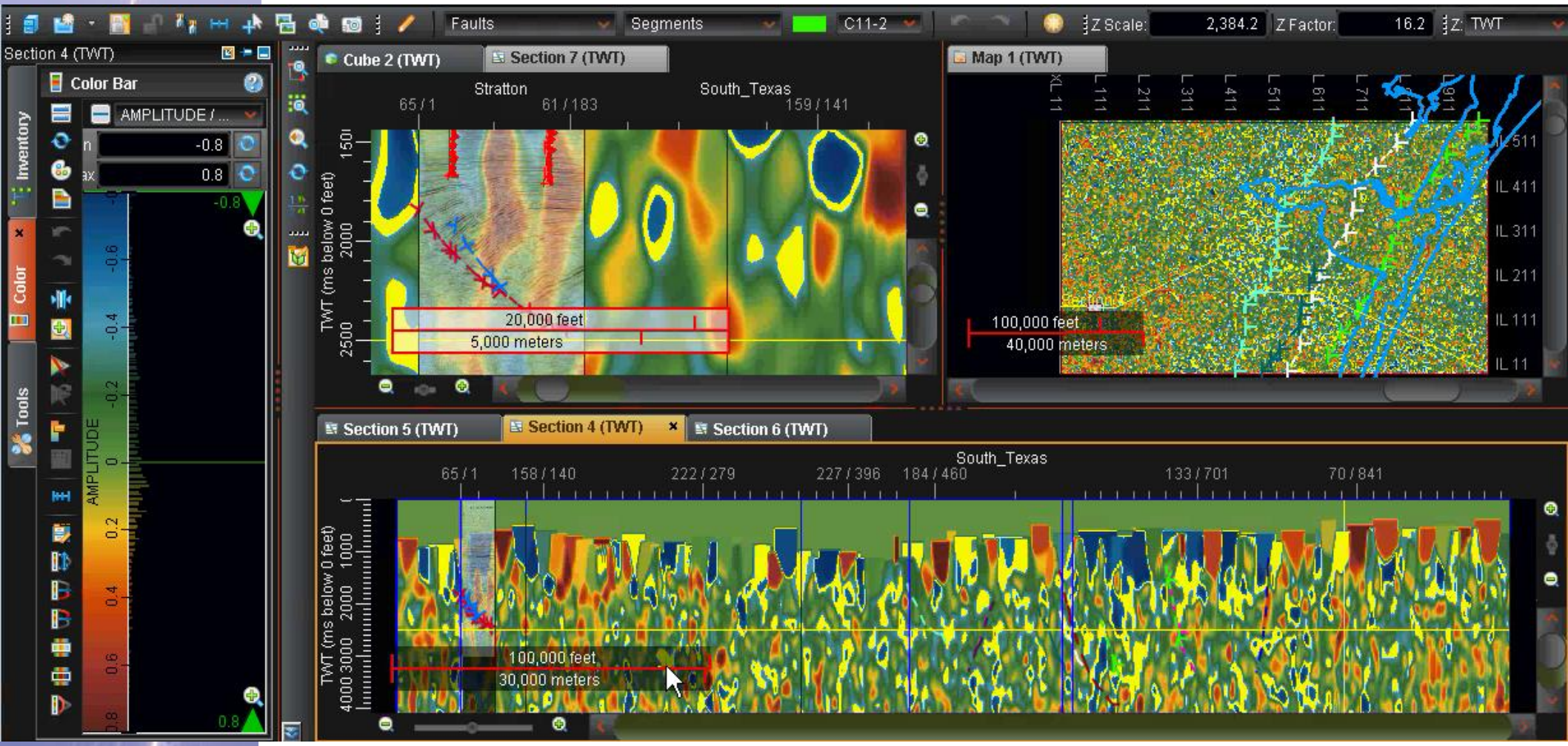
Lightning Attribute - Symmetry



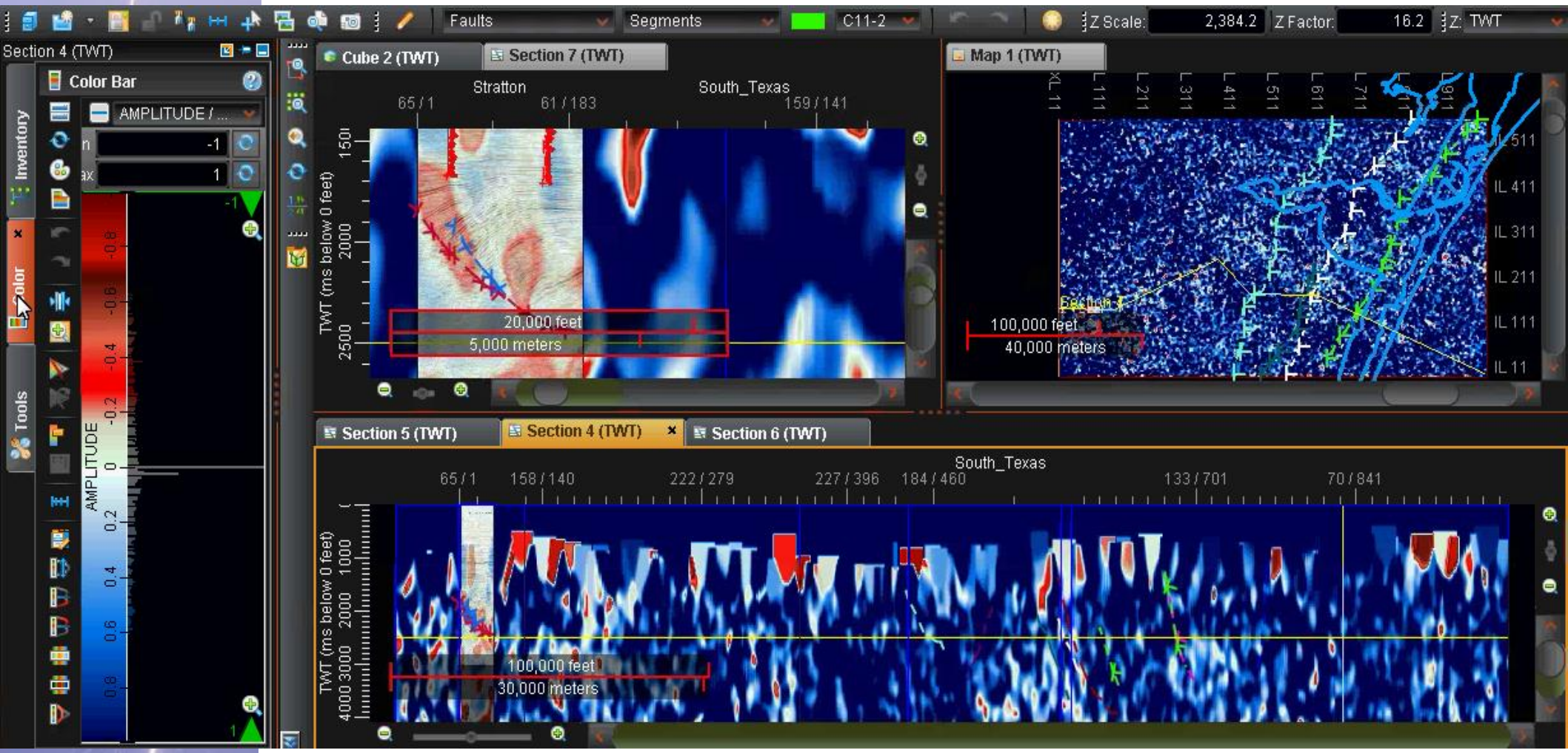
Lightning Attribute - Tidal Gravity



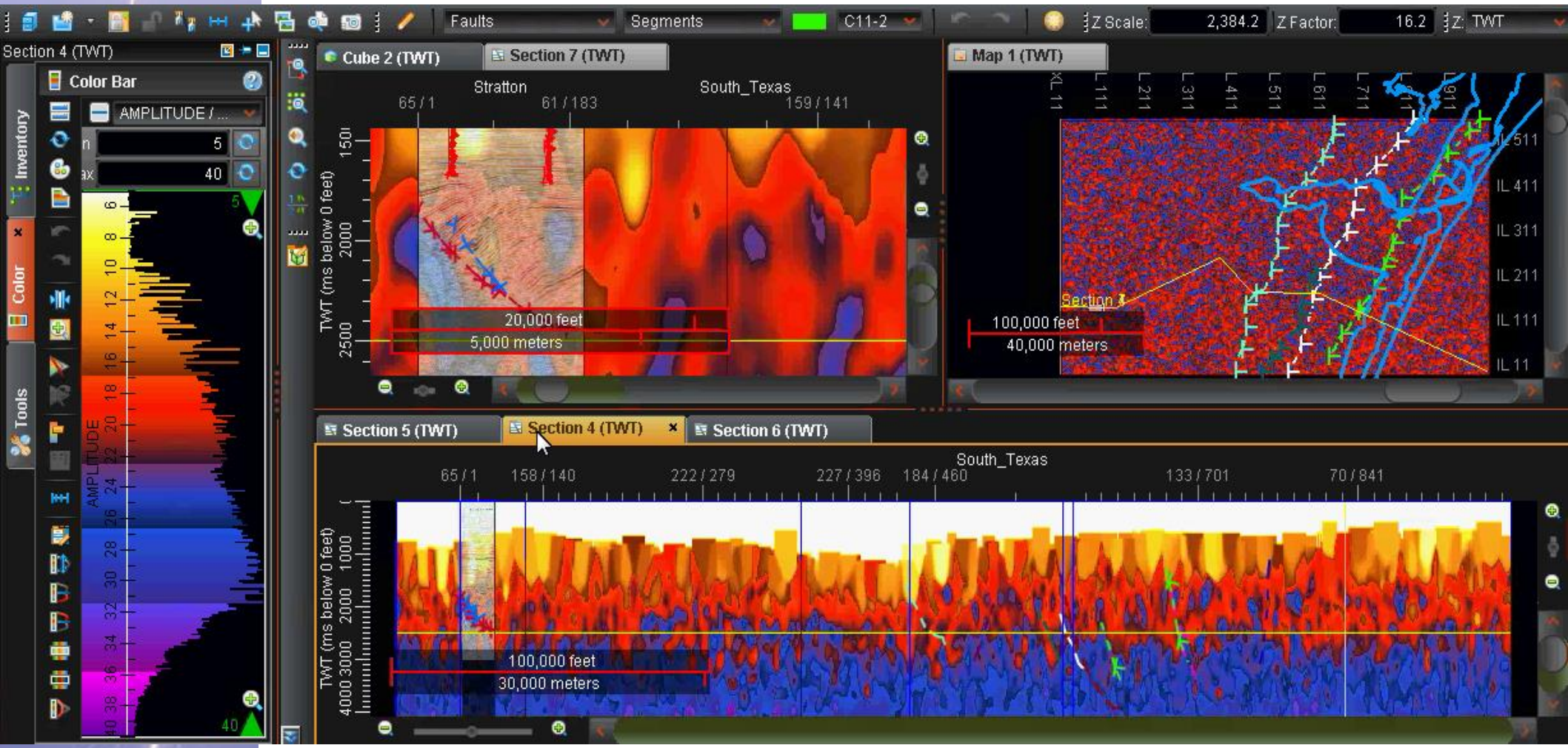
Lightning Attribute - Tide



Lightning Attribute - Tide Gradient



Lightning Attribute -Total Wavelet Time



Applications of Lightning Technology

Geohazard investigations in areas with poor or fragmented data sets.

Regional / Trend Analysis
Play Fairway
Fill gaps between data sets – 3D, 2D, wells.
Areas hard to image with seismic
Possibly variations in reservoirs over time?
Possible variations in fluid movement related to earthquakes?

Mineral Exploration
Pyrite halo mapping in copper mining exploration; supplement to aeromag.

Geothermal Play Fairway Exploration

Special Thanks to…

BYU Interns Dustin Northrop and R. Corbin Lewis
Great job on the figures!

Tom Ewing (BEG) for superb regional geology of Corpus Christi Area – just what we needed.

Bob Hardage, (BEG) for the seismic that started this project rolling.

BEG Geologists Raul, Solis, and Galloway for their contributions to our understanding of stratigraphy and faulting in our study area.

Robert Schneider – Short Course sparked many ideas!

Thank You!

www.dynamicmeasurement.com

www.dynamicmeasurement.com/TAMU

www.dynamicmeasurement.com/LI

- Kathy Haggar, Geologist
  - cell: 225.953.1076
  - e-mail: kathy@dynamicmeasurement.com
- Les Denham, Chief Geophysicist
  - cell: 713.962.3964
  - e-mail: les@dynamicmeasurement.com
- H. Roice Nelson, Jr., Geophysicist
  - cell: 713.542.2207
  - e-mail: roice@dynamicmeasurement.com

- P.O. Box 40873
  Old Hammond Highway
  Baton Rouge, LA 70835
- 211 Baker Road #382
  Barker, TX 77413
  - Office: 281.579.0172
- 2155 West 700 South #31
  Cedar City, UT 84720
  - Fax: 435.267.2668