

# **Application of the Instantaneous Quality Factor (Q) in the Characterization of the Austin Chalk and Eagle Ford Shale, South Texas\***

**Osareni Ogiesoba<sup>1</sup>**

Search and Discovery Article #41781 (2016)\*\*

Posted March 21, 2016

\*Adapted from oral presentation at Geoscience Technology Workshop, Unconventionals Update, Austin, Texas, November 3, 2015

\*\*Datapages © 2016 Serial rights given by author. For all other rights contact author directly.

<sup>1</sup>Bureau of Economic Geology, The University of Texas at Austin, Austin, TX, USA ([osareni.ogiesoba@beg.utexas.edu](mailto:osareni.ogiesoba@beg.utexas.edu))

## **Abstract**

Although the relationship between rock physical properties and the quality factor (Q) attribute has been recognized for several decades, the exploration community has not taken advantage of this attribute in reservoir characterization. Despite the fact that Q is a very powerful tool for detection of hydrocarbons and can help in the identification of brittle zones within unconventional resource plays, it has been featured less in hydrocarbon exploration than other seismic attributes such as reflection strength (amplitude envelope). This paper intends to demonstrate the importance of Q by presenting results of the application of instantaneous Q in the characterization of the Austin Chalk and Eagle Ford Shale within the Maverick Basin in South Texas. The method entails the computation of Q volume from 3D seismic data and then calibrates output with wireline logs. Wireline logs employed in this exercise include porosity, resistivity (deep induction), log-calculated total organic carbon (TOC), and water saturation logs to identify hydrocarbon sweet spots within the Austin Chalk and Eagle Ford Shale.

The linear relationship obtained by crossplotting Q traces versus log properties at well locations has enabled, in conjunction with other seismic attributes, hydrocarbon sweet-spot prediction within the Eagle Ford Shale and Austin Chalk. Results show that Q increases as acoustic impedance increases (i.e., increasing velocity), suggesting that Q can be used to identify high-velocity rocks such as brittle carbonate zones within shale intervals. In addition, the linear relationship between Q and TOC shows that Q increases as TOC increases, suggesting that the Eagle Ford Shale is a unique type of shale in which TOC increases with increasing carbonate (calcite) content. Similar results show that resistivity increases with increasing carbonate, suggesting that hydrocarbons are contained within carbonate-rich zones. However, relationships between Q and porosity and water saturation

show that Q decreases as these log properties increase. These relationships are not confined to the Eagle Ford or Austin Chalk. The same types of relationships are observed in the Georgetown Formation, which is overlain by the Del Rio Formation below the Eagle Ford Shale. The conclusion based on the foregoing is that Q is a powerful tool that can be employed in hydrocarbon exploration in any geologic setting.

### Selected References

- Dctpgu.'C0'3; ; 4.'Ecrewv'kq'qh'kpuvcpvpgqwu'ltgs wge{ 'cpf'kpuvcpvpgqwu'dcpf y kf yj '\*uj qtv'pqw+.'I gqr j { uku.'79.'3742'37460  
"
- Barnes, A.E., 1993, Instantaneous spectral bandwidth and dominant frequency with applications to seismic reflection data: Geophysics, v. 58/3, p. 419-428.  
"
- Johnston, D.H., and M.N. Toksöz, 1981, Definitions and terminology: in M.N. Toksöz, and D.H. Johnston, eds., Seismic Wave Attenuation, Society of Exploration Geophysicists, p. 1-5.  
"
- Mavko, G.M., and A. Nur, 1978, The effect of nonelliptical cracks on the compressibility of rocks: Journal of Geophysical Research, v. 83/B9, p. 4459-4468.  
"
- O'Connell, R.J., and B. Budiansky, 1977, Viscoelastic properties of fluid-saturated cracked solids: Journal of Geophysical Research, v. 82, p. 5719-5735.  
"
- Passey, Q.R., S. Creaney, J.B. Kulla, F.J. Moretti, and J.D. Stroud, 1990, Practical Model for Organic Richness from Porosity and Resistivity Logs: AAPG Bulletin, v. 74, p. 1777-1794.  
"
- Passey, Q.R., K.M. Bohacs, W.L. Esch, R. Klimentidis, and S. Sinha, 2010, From oil-prone source rock to gas-producing shale reservoir - geologic and petrophysical characterization of unconventional shale gas reservoirs: SPE 131350, International Oil and Gas Conference and Exhibition in China, 8-10 June, Beijing, China.

# **APPLICATION OF THE INSTANTANEOUS QUALITY FACTOR (Q) IN THE CHARACTERIZATION OF THE AUSTIN CHALK AND EAGLE FORD SHALE, SOUTH TEXAS**

**Osareni Ogiesoba**

**Bureau of Economic Geology, The  
University of Texas at Austin**



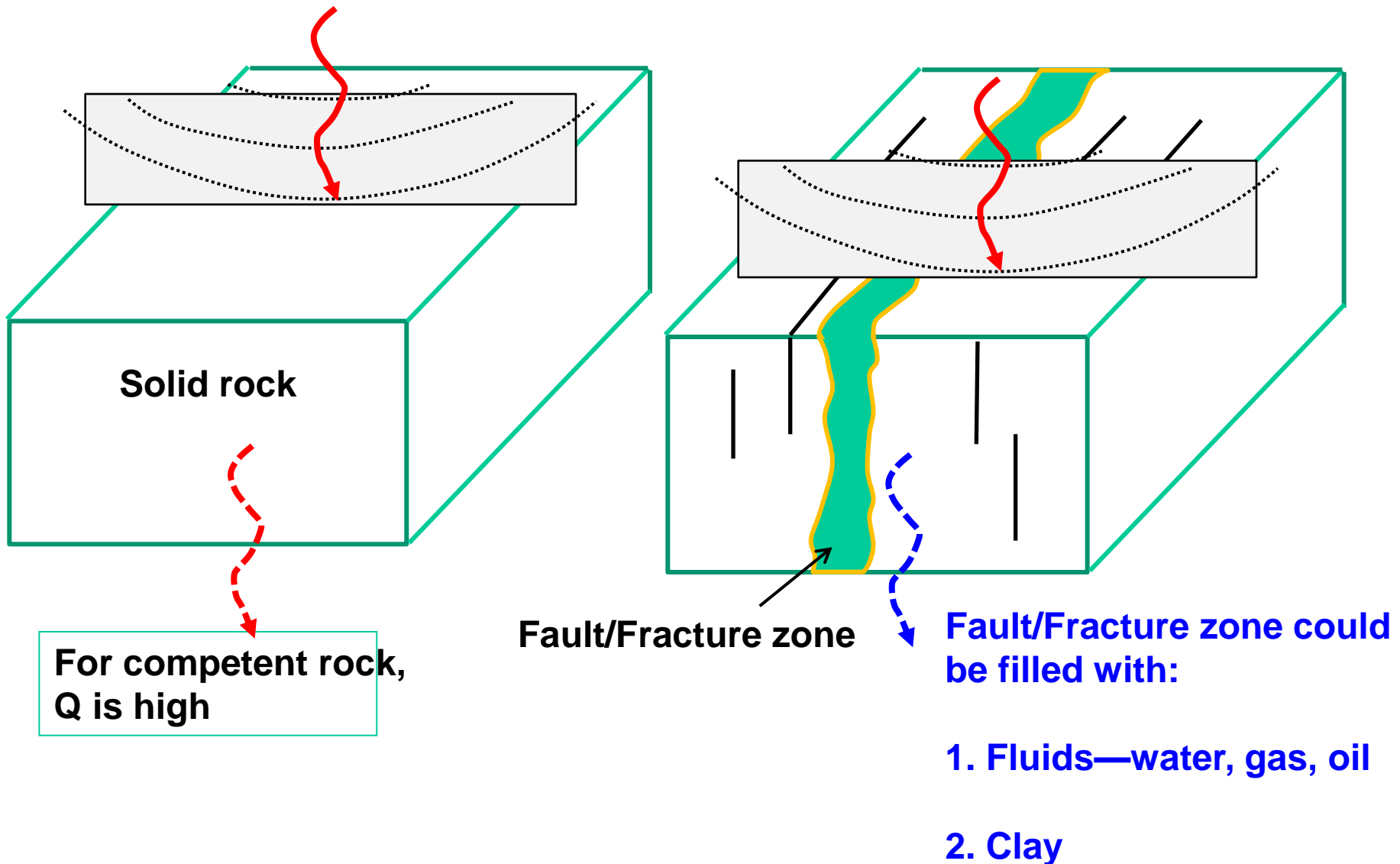
**BUREAU OF  
ECONOMIC  
GEOLOGY**



# Overview

- **Review of instantaneous quality factor (Q)**
- **Review of laboratory observations**
- **Application of Q in hydrocarbon exploration:  
Examples from Austin Chalk and Eagle Ford Shale**
- **Summary and Conclusions**

# Review of instantaneous Q



# Review of instantaneous Q

$$A = A_0 \frac{x_0}{x} e^{-\alpha x} \quad (1)$$

Where  $A$  is the amplitude at distance  $x$  from the source,

$A_0$  is the amplitude at distance zero

$\alpha$  is the absorption coefficient.

# Commonly used measures of attenuation

- Attenuation coefficient  $\alpha$  which is the exponential decay constant of the amplitude of a plane wave traveling in a homogeneous medium
- Quality factor  $Q$  and its inverse  $Q^{-1}$ , sometimes called internal friction or dissipation factor
- Logarithmic decrement  $\delta$

(Johnston and Toksoz, 1981)

# Commonly used measures of attenuation

## Cont'd

$$\frac{1}{Q} = \frac{\alpha v}{\pi f} = \frac{\delta}{\pi} \quad (2)$$

Where  $f$  = frequency, and  $v$  = velocity, is the logarithmic decrement

$$\delta = \ln \left[ \frac{A_1}{A_2} \right] = \frac{\alpha v}{f} \quad (3)$$

Johnston and Toksoz, 1981



# Commonly used measures of attenuation Cont'd

Standard definition of Q:

$$Q = \frac{\omega E}{-dE/dt} \quad (4)$$

Where E = stored energy in the system, dE/dt is rate of energy loss

Johnston and Toksoz, 1981

# Instantaneous Quality Factor (Q)

$$Q(t) = \frac{f(t)}{2\sigma(t)}, \quad (5)$$

$$\text{where } \sigma(t) = \frac{1}{2\pi} * \left| \frac{d}{dt} \log_e A(t) \right| \quad (6)$$

$$Q(t) = \frac{\pi f(t)}{\frac{d}{dt} (\log_e A(t))} \quad (7)$$

$$= \pi f(t) * \left( \frac{A(t)}{\frac{d}{dt} A(t)} \right) \quad (8)$$

$$= \pi f(t) * \left( \frac{\text{stored energy}}{\text{rate of energy loss}} \right) \quad (9)$$

**f** = instantaneous frequency, **A** = instantaneous amplitude envelope: [Barnes, 1992, 1993](#)

# Comparison of Instantaneous Quality Factor $Q(t)$ and Intrinsic ( $Q$ )

$$Q(t) = \pi f(t) * \left( \frac{A(t)}{\frac{d}{dt} A(t)} \right)$$

$$= \pi f(t) * \left( \frac{\text{stored energy}}{\text{rate of energy loss}} \right)$$

**Barnes (1992, 1993)**

$$Q = \omega \left( \frac{E}{dE/dt} \right) \quad (5)$$

$$= \omega * \left( \frac{\text{stored energy}}{\text{rate of energy loss}} \right)$$

**Johnston and Toksoz, 1981**

# **Results from laboratory experiments**

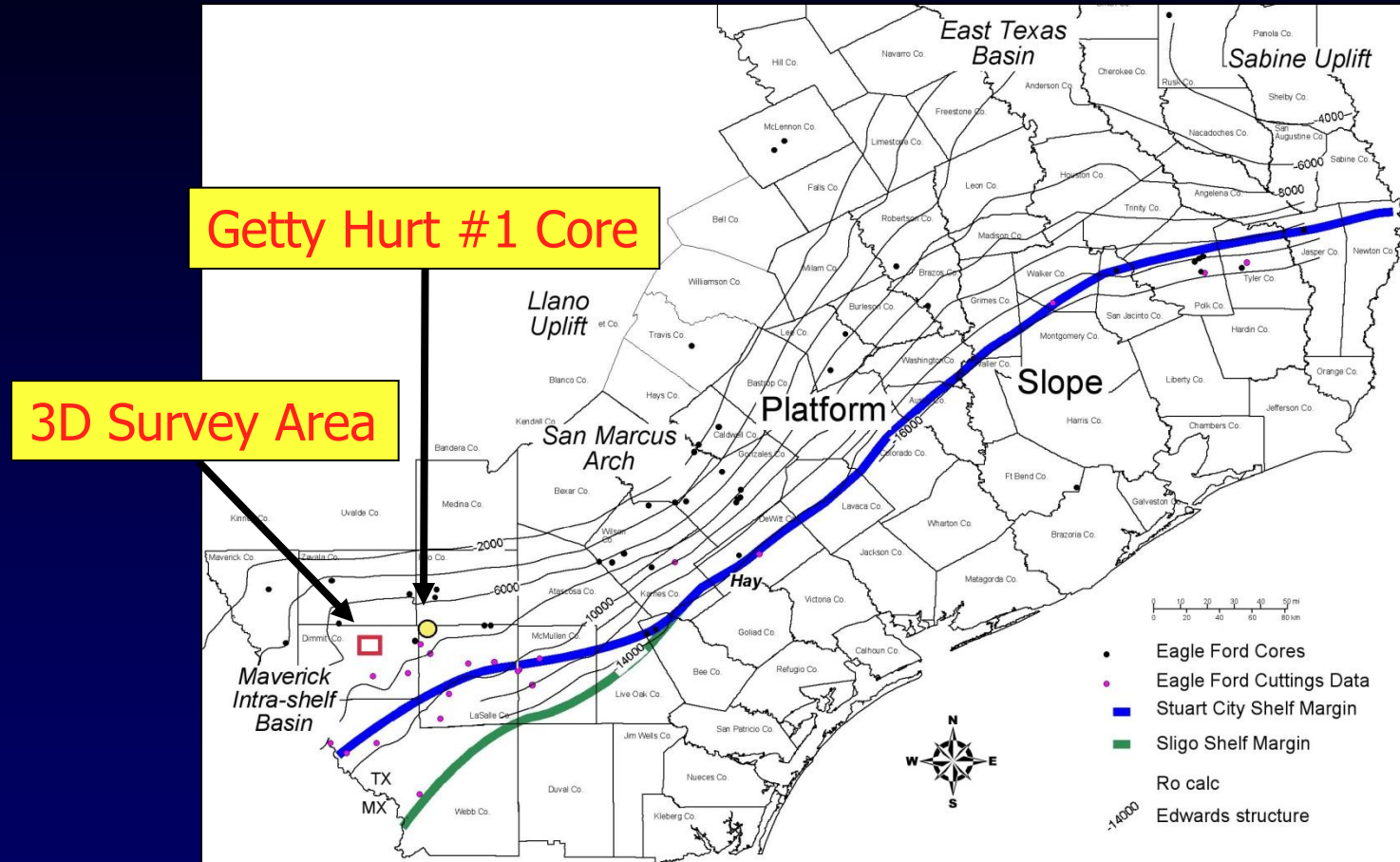
- **Dependence on frequency—Johnston and Toksoz, 1981**
- **Dependence on degree of saturation—Mavko and Nur, 1978**
- **Decreases as saturation increases—Wyllie et al., 1962, Johnston et al., 1978**
- **Decreases as porosity increases—Wyllie et al., 1962**
- **Increases as velocity increases—Wyllie et al., 1962**
- **Increases as pressure increases—Johnston et al., 1978**
- **Dependence on cracks' interconnectivity—O'Connell and Budiansky, 1977**

# **Uses of instantaneous Q in exploration**

- **Because it is a transmissive attribute similar to interval and instantaneous velocities, it has strong relation to:**
  - (1) porosity**
  - (2) permeability**
  - (3) fractures**
- **It indicates local variation of Q factor, similar to relative acoustic impedance computation from the seismic trace**
- **Indicates relative absorption characteristics of beds**

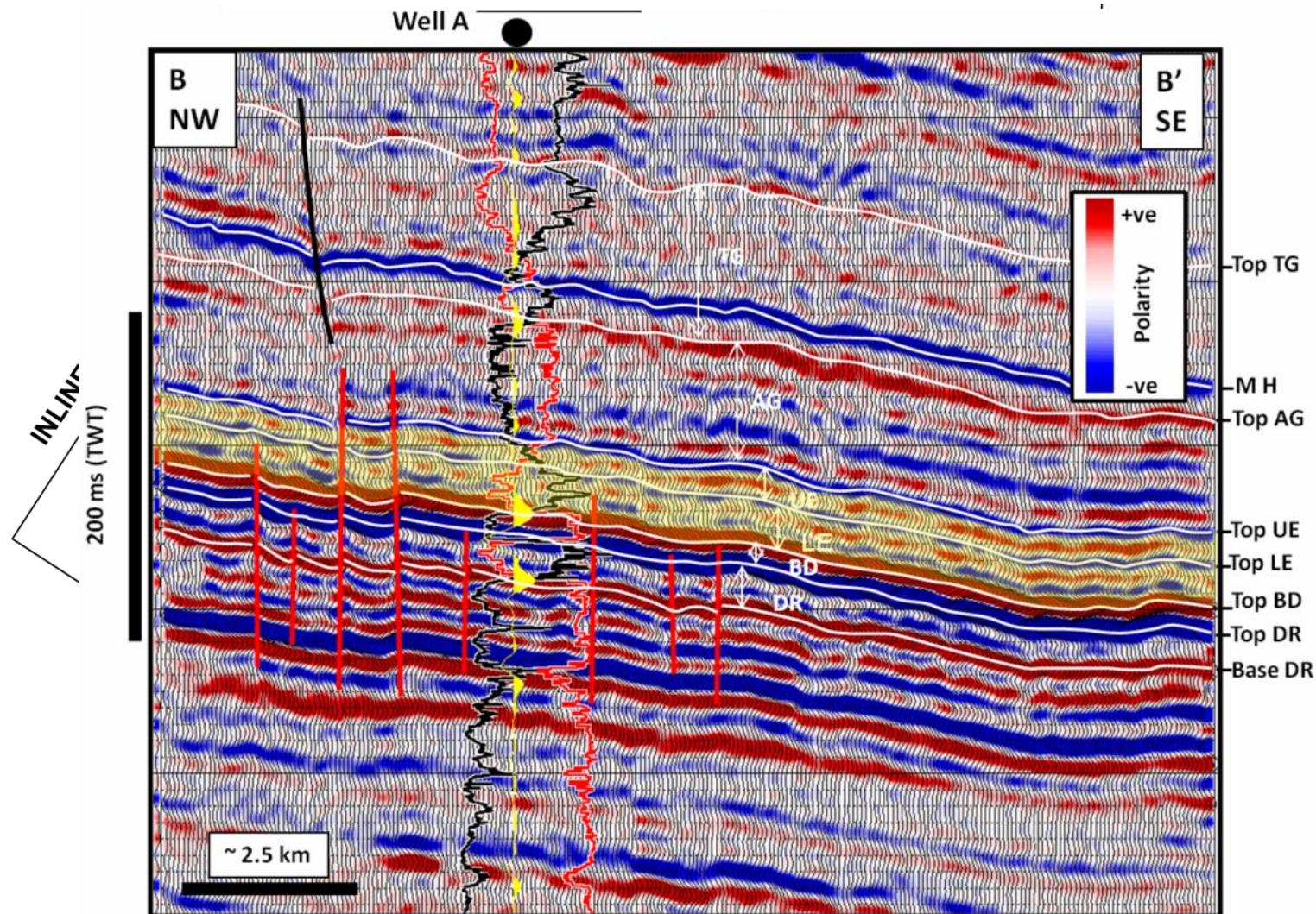
**Application of Instantaneous Q from  
surface seismic: Examples from  
Cretaceous Austin Chalk and Eagle ford  
Shale—Maverick Basin**

# Location of 3D Seismic Survey





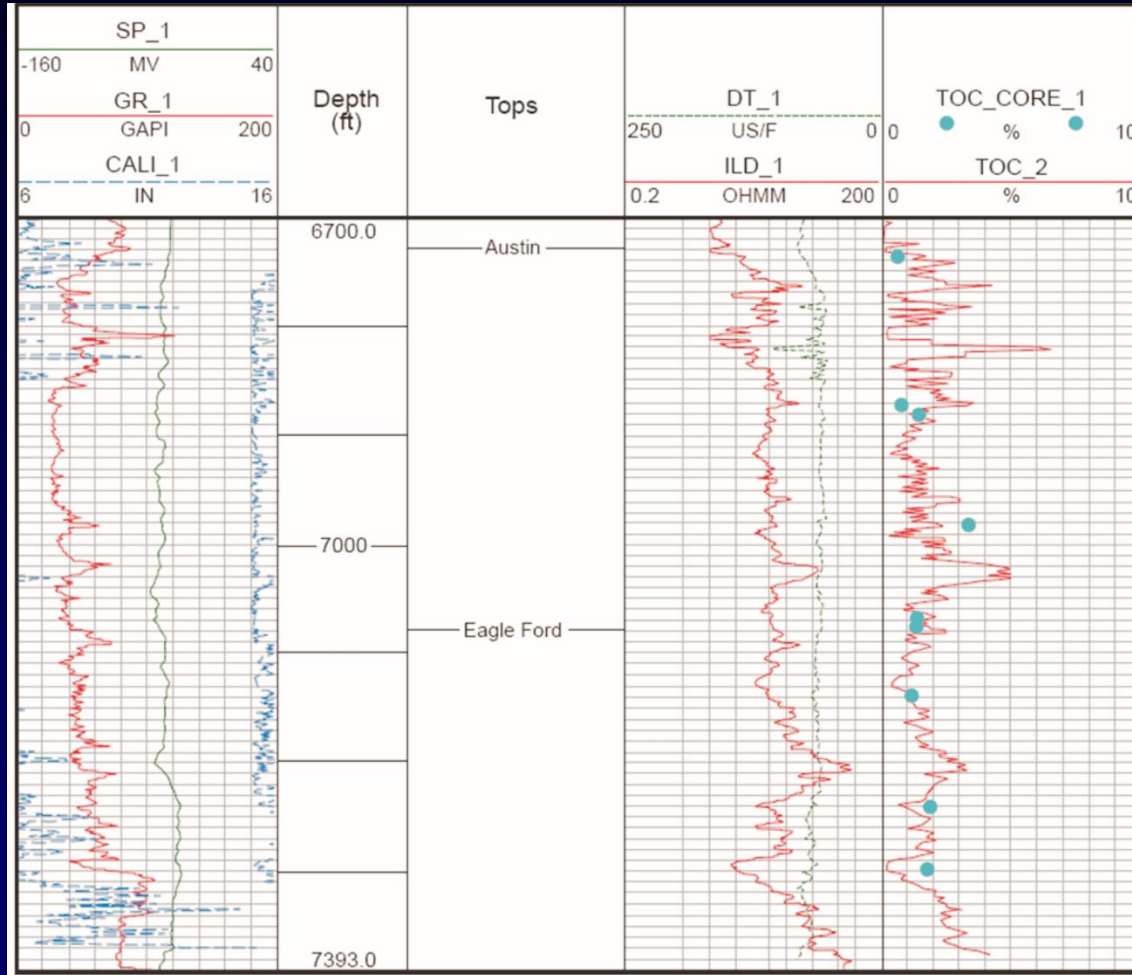
# 3D Survey Area and typical seismic data



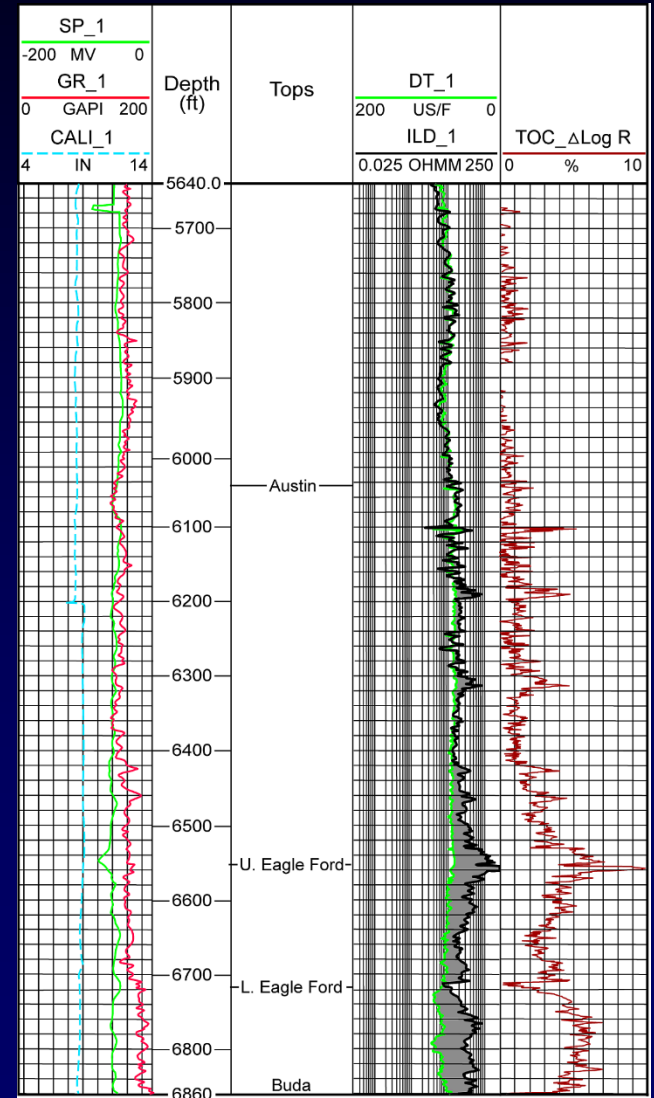


# Objective—Predict total organic carbon (TOC) and resistivity volumes

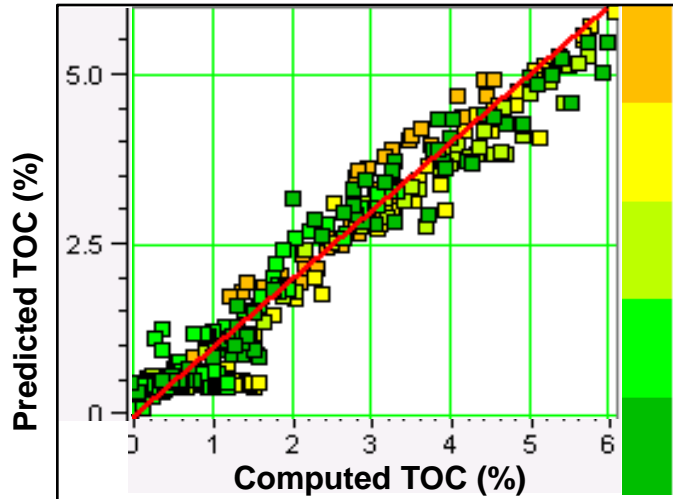
Log-calculated TOC from Cored well



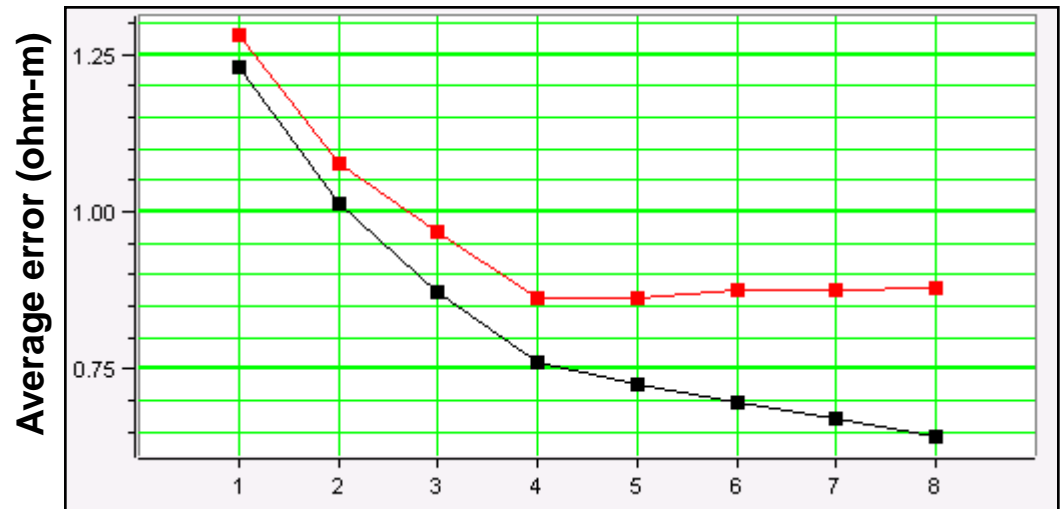
Derived using Passey et al. (1990, 2010) equations



# TOC prediction



Correlation coefficient = 0.96



Number of attributes

## Attributes

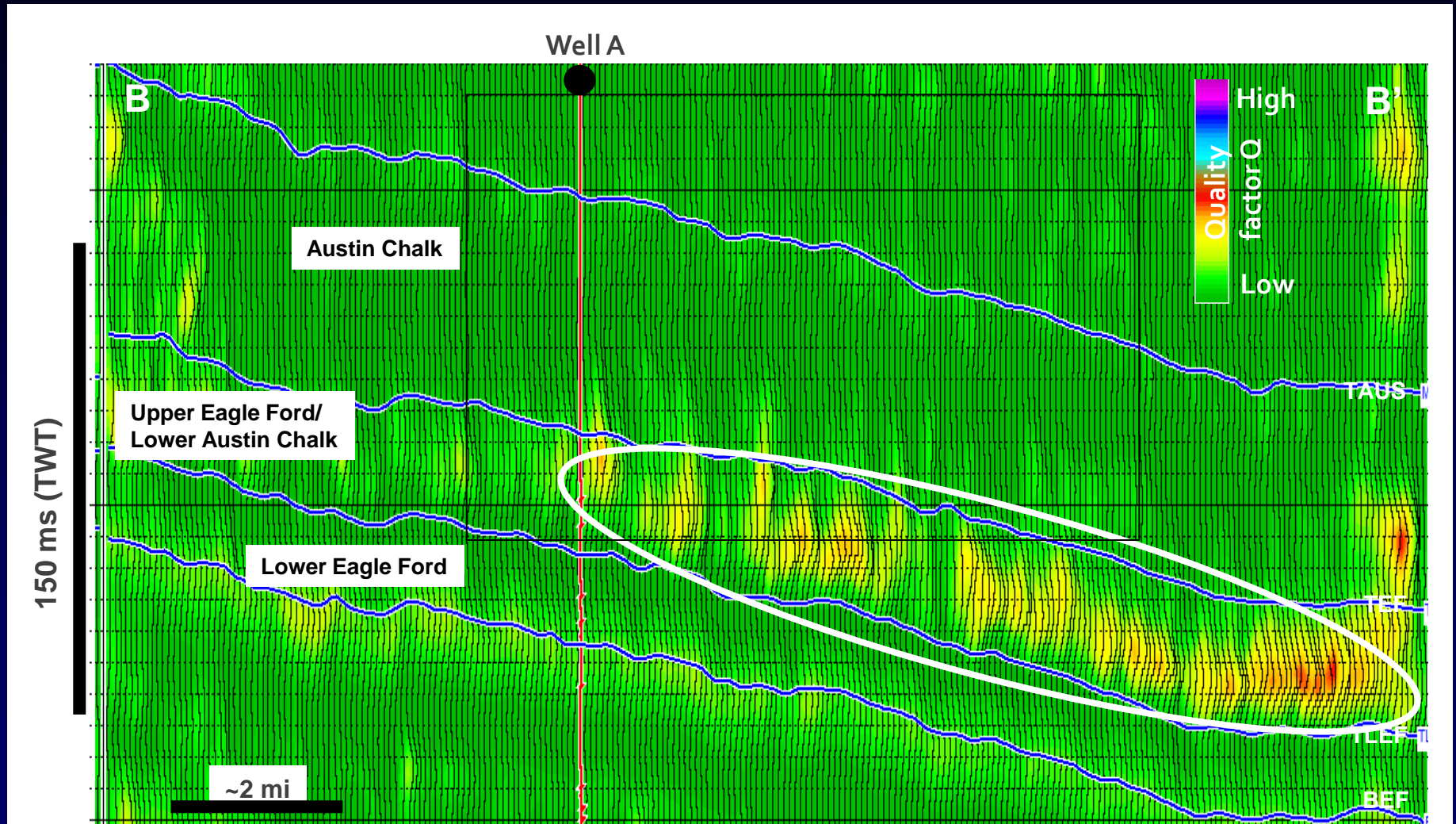
Quality factor Q

Gamma ray

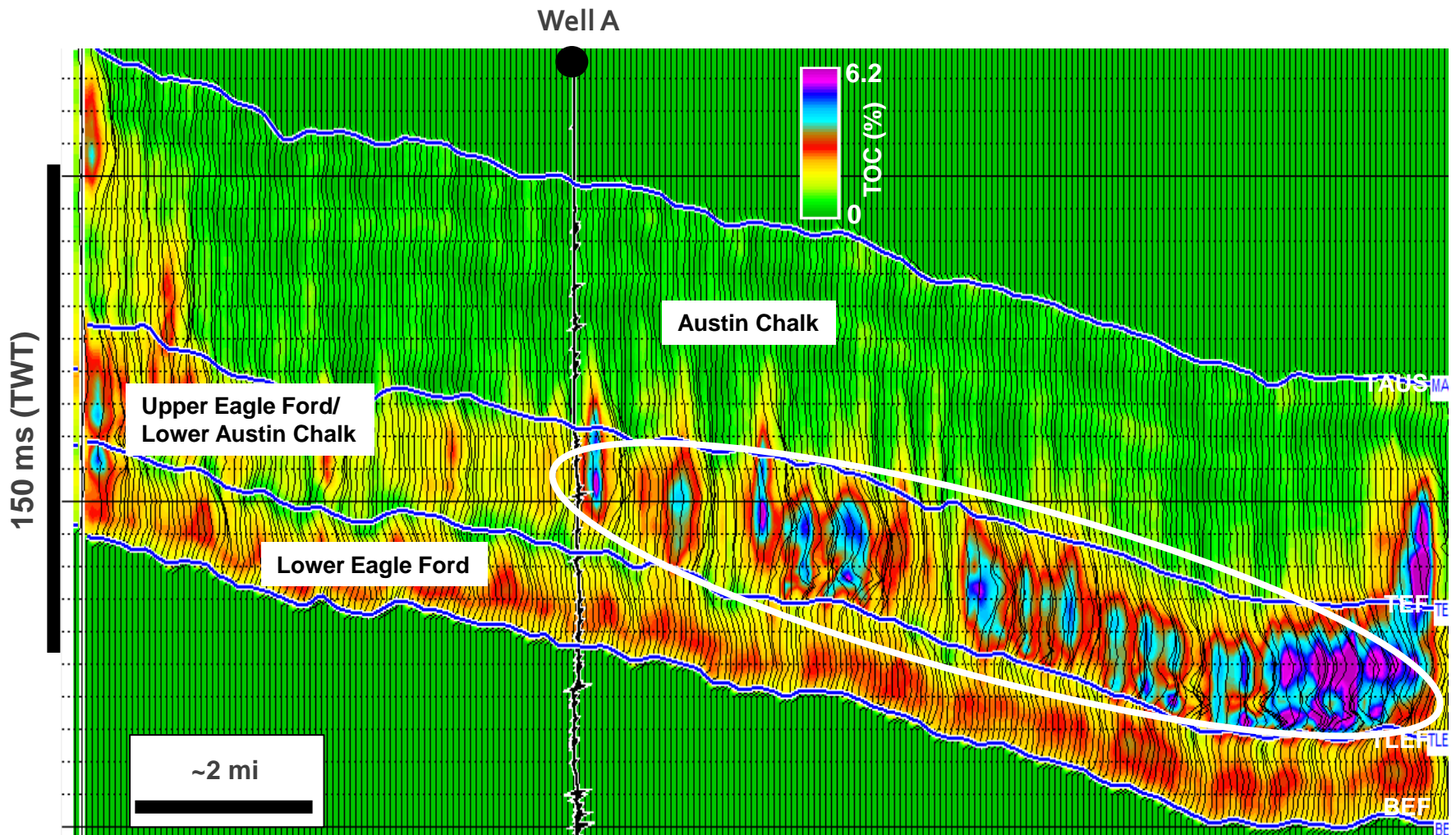
Derivative of instantaneous amplitude

Amplitude-weighted cosine of phase

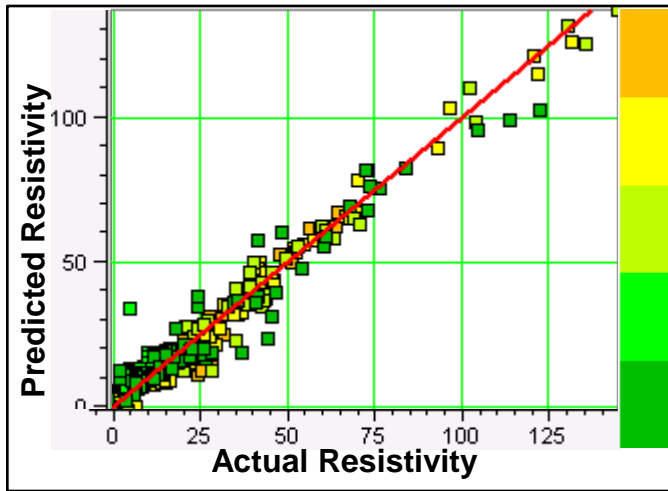
# Instantaneous Q along transect B—B'



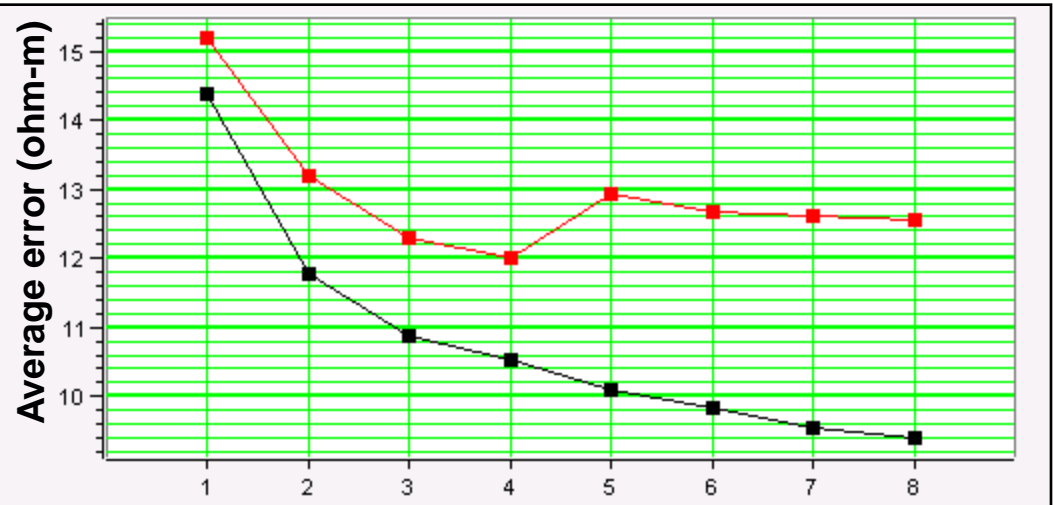
# Predicted TOC along Transect B—B'



# Resistivity prediction



Correlation coefficient = 0.98



Number of attributes

Attributes

Quality factor Q

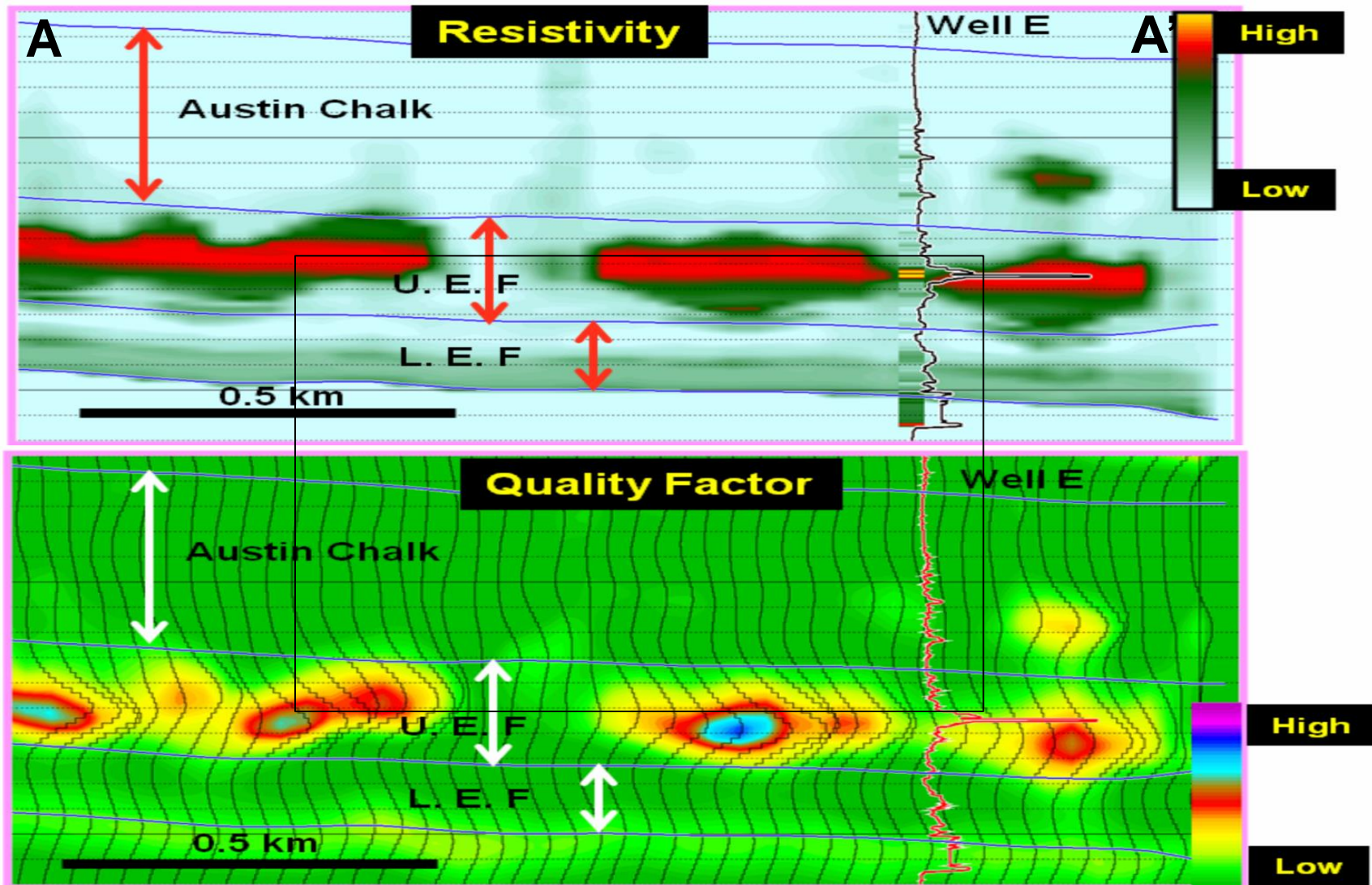
Average frequency

Derivative

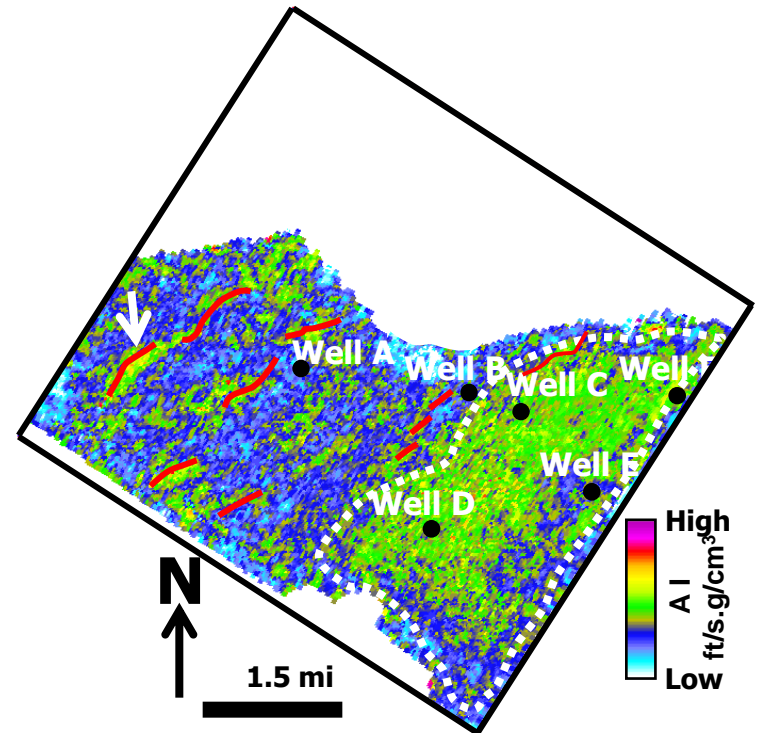
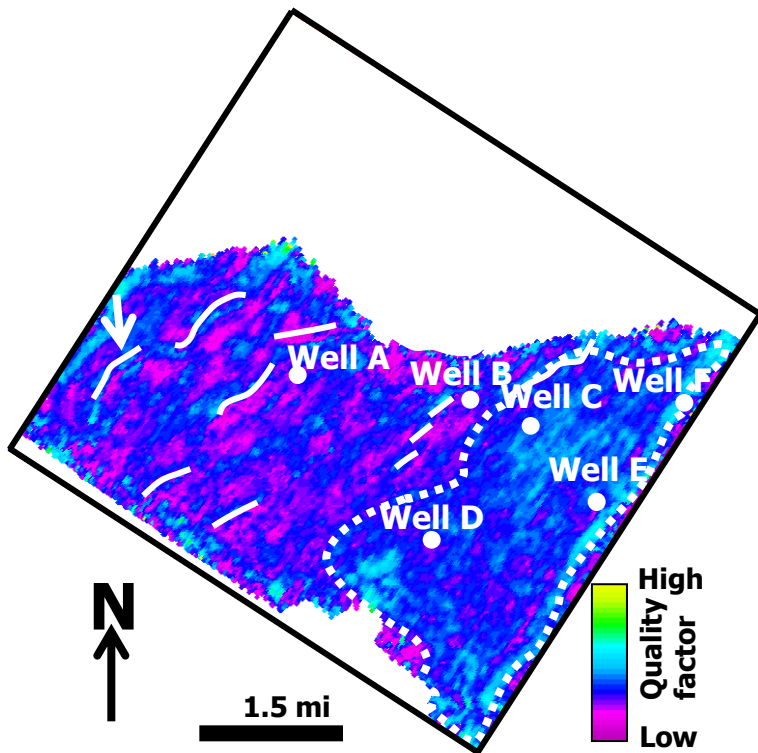
Filter 15-20-25-30



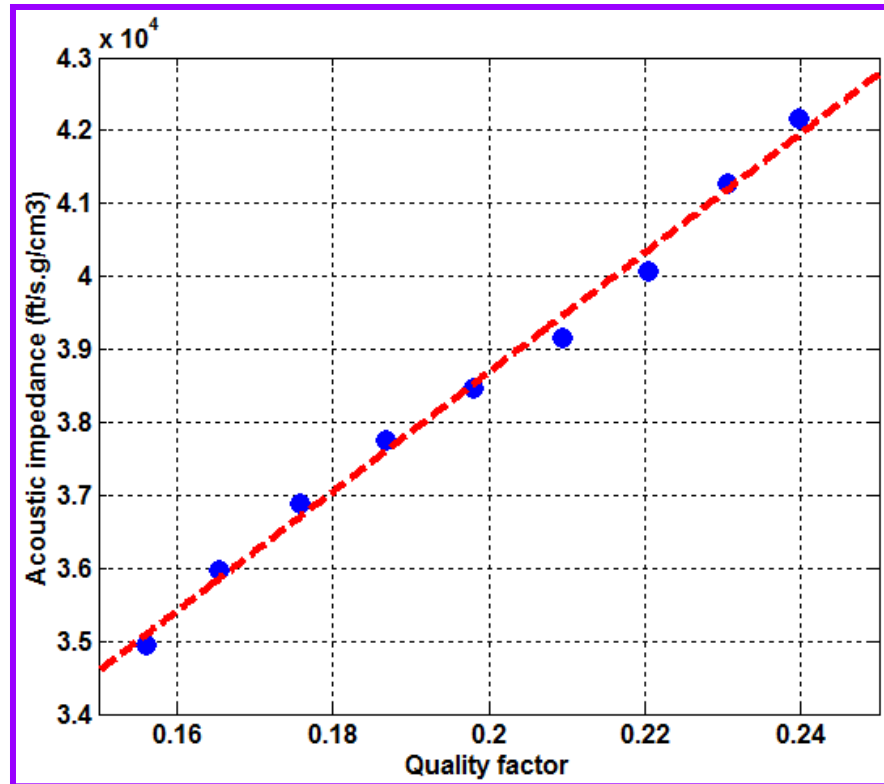
# Predicted resistivity vs instantaneous Q along transect A—A'



# Acoustic impedance (AI) vs Q within the Eagle Ford Shale

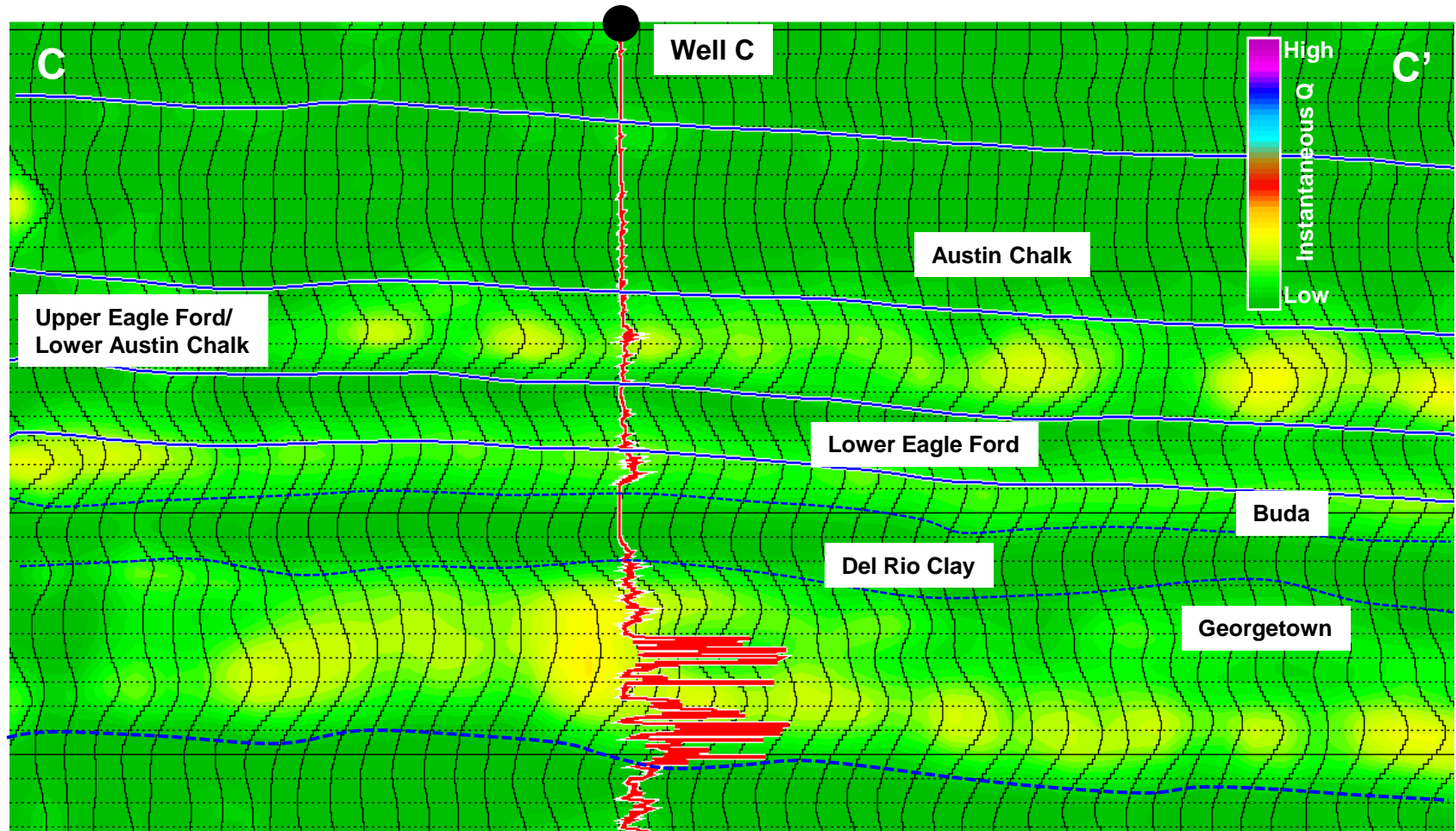


# Acoustic impedance (AI) vs Q within the Eagle Ford Shale

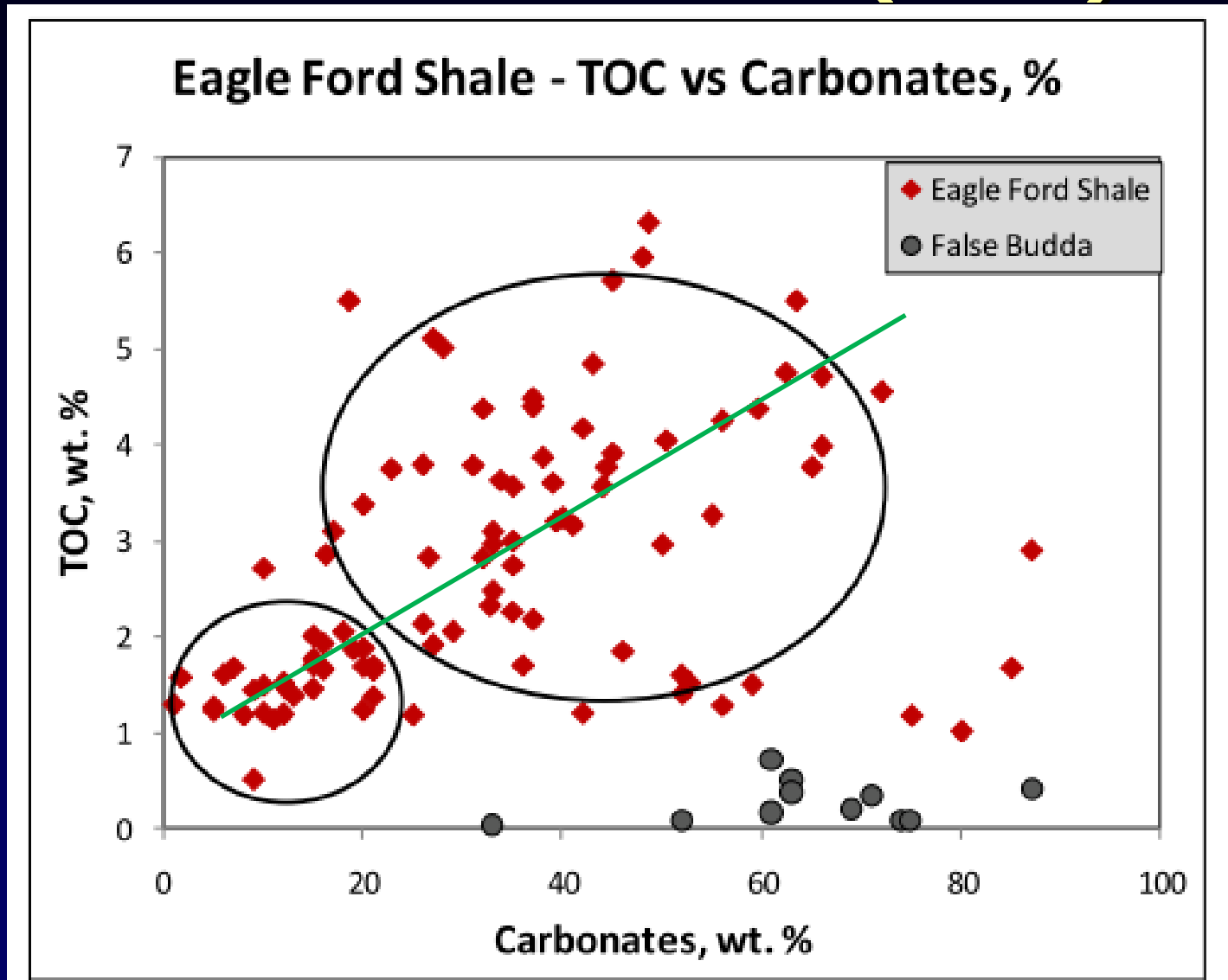




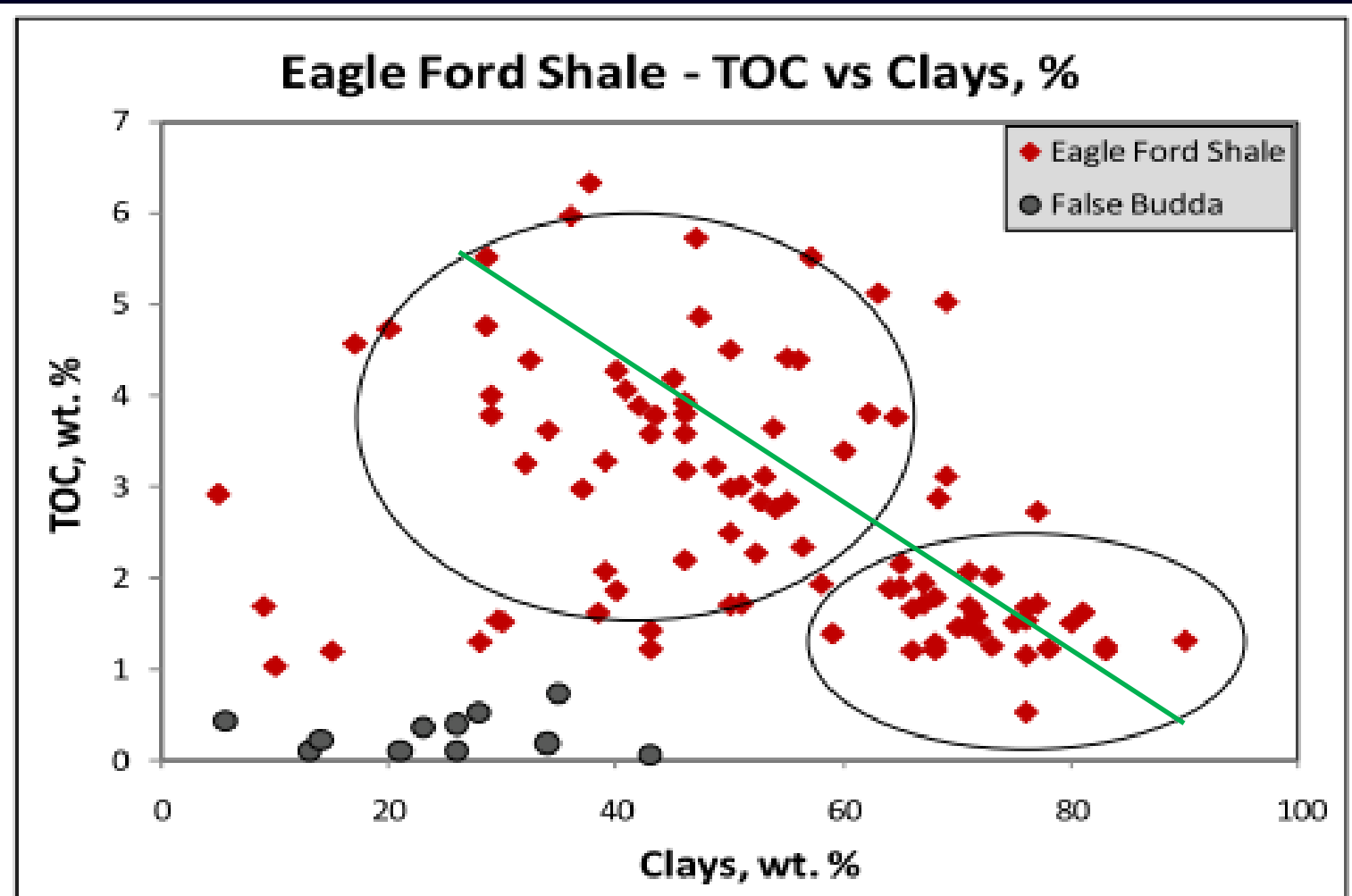
# Quality factor (Q) transect with resistivity (deep induction) log along transect C—C'



# TOC (%) vs Carbonate composition correlation—Sondhi (2011)



# TOC (%) vs Clay composition correlation—Sondhi (2011)



# Summary and Conclusions

- Reviewed equations for computing Q attribute
- Showed examples of areas where Q has been used in reservoir characterization
- Q attribute is a very powerful tool for reservoir characterization that is under utilized
- Successful application of Q may depend on
  - Age of the rock—more successful in older rocks
  - Rock type—more successful in carbonates

# **Summary and Conclusions Cont'd**

- **High TOC and high-resistivity zones correlate with high Q zones**
- **Q increases as acoustic impedance (AI) increases**
- **The Eagle Ford Shale is a unique shale in which TOC increase with increase in carbonate composition**
- **High resistivity zones correlate with high Q zones within Georgetown Formation**
- **Because high AI zones imply brittle zones (i.e., high velocity zones), high Q zones also imply brittle zones**
- **Therefore, Q attribute can be used to identify brittle zones and hydrocarbon sweet spots within the Eagle Ford Shale, Austin Chalk, and other areas with similar geology**

# **Acknowledgments**

- **Landmark Graphics University Grant**
- **Hampson and Russell Software**
- **CML Exploration**

# Thank you



BUREAU OF  
ECONOMIC  
GEOLOGY