Understanding Lithologic Significance of Amplitude Envelope and Acoustic Impedance within Oligocene and Miocene Strata, South Texas Gulf Coast*

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Search and Discovery Article #40577 (2010)
Posted July 30, 2010

*Adapted from oral presentation at AAPG Annual Convention and Exhibition, New Orleans, Louisiana, April 11-14, 2010

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Abstract

Distinguishing between sand- and shale-rich sediments is key to delineating economically viable prospects within a sedimentary basin. Researchers have noted that high seismic amplitudes indicate sand-prone sediments, and, as such, could be used to search for sand-rich zones. Whereas this observation may be correct to some extent, amplitude anomalies depend on a variety of geologic variables such as depositional environments, geopressure, fluid content, source of sediment supply, burial depth, age, diagenesis, etc. In this study, we integrated seismic attribute, acoustic impedance, sequence stratigraphic and wireline-log analyses to investigate the significance of high amplitudes within selected Oligocene and Miocene intervals along the South Texas Gulf Coast. We calibrated gamma-ray and resistivity logs to 3-D seismic data using synthetic seismograms to associate lithology with seismic data and then generate acoustic impedance (AI) logs and instantaneous amplitude envelope (amplitude) volume. We identified and tied different depositional systems tracts to the seismic data. By cross-plotting logs and amplitude traces, we attempted to establish a relationship between amplitudes and lithology, as well as a relationship between amplitude and AI that could be used to predict lithology in each of the different systems tracts. Our seismic analysis of various systems tracts from two different subbasins show that correlation between high amplitudes and lithology depends on individual systems tracts and basin location. High amplitudes and high AI in a transgressive systems tract in one subbasin were indicative of sand-prone zones, whereas the same attributes were indicative of shales in the transgressive systems tract of another subbasin. Similar observations were recorded in the highstand and lowstand systems tracts. However, if several systems tracts are combined into one zone for seismic analyses no direct correlation is observed between amplitude and lithology. Therefore, seismic analyses of amplitudes should be performed within individual systems tracts when relating amplitudes to lithology.

Reference

Bracewell, R.N., 1965, The Fourier Transform and Its Applications: McGraw-Hill, New York, 386 p.

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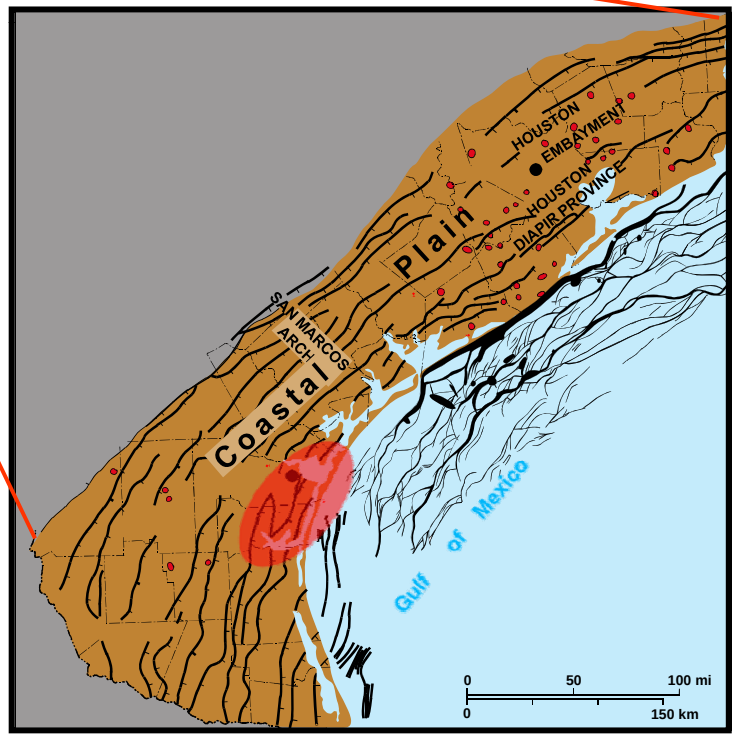
Overview

- Introduction
- Objectives
- Brief description of amplitude envelope
- Brief explanation of S5 log
- Relationship between amplitude envelope, acoustic impedance and gamma-ray within the Miocene and Oligocene from two subbasins:

  (1) Redfish Bay
  (2) Laguna Madre

- Conclusions

Introduction: Location



STUDY AREA

Objectives

- Obtain linear relationship between lithology and amplitude envelope (AE) and also between acoustic impedance (AI) and lithology that could be used to infer lithology within individual systems tracts in the survey area.

Amplitude envelope (AE)

The modulus (amplitude envelope) is given as

$$A(t) = (f^2(t) + h^2(t))^{1/2}, \qquad (1)$$

where *f(t)* is the amplitude of the real seismic trace,
and *h(t)* is the quadrature expressed by Bracewell (1965) as:

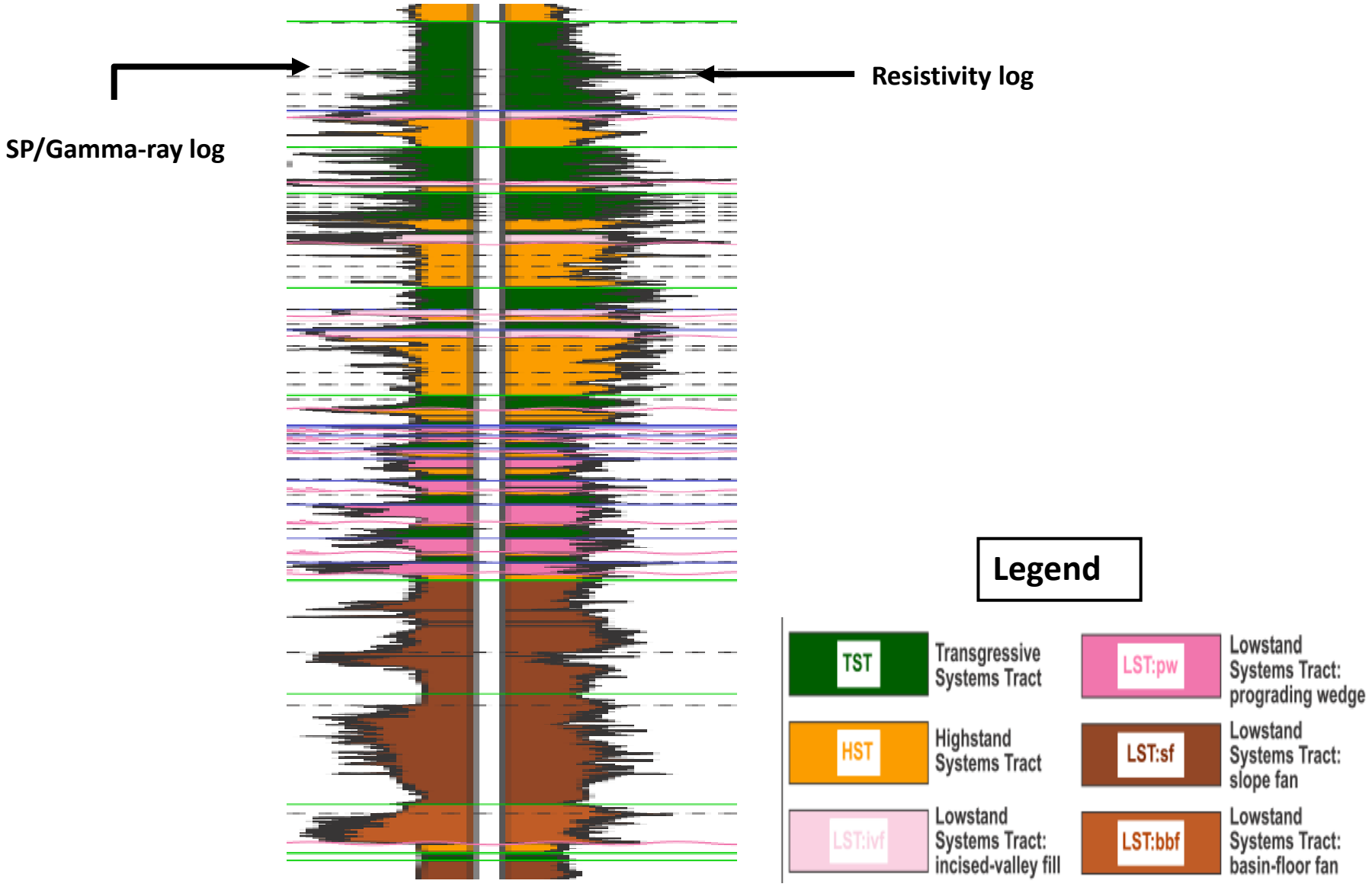
$$h(t) = 1/\pi t * f(t), \qquad (2)$$

where * denotes convolution.

Amplitude envelope is always positive and does not depend on phase.

It is used for fault delineation and lithology differentiation.

An example of typical S5 log from South Texas Gulf Coast



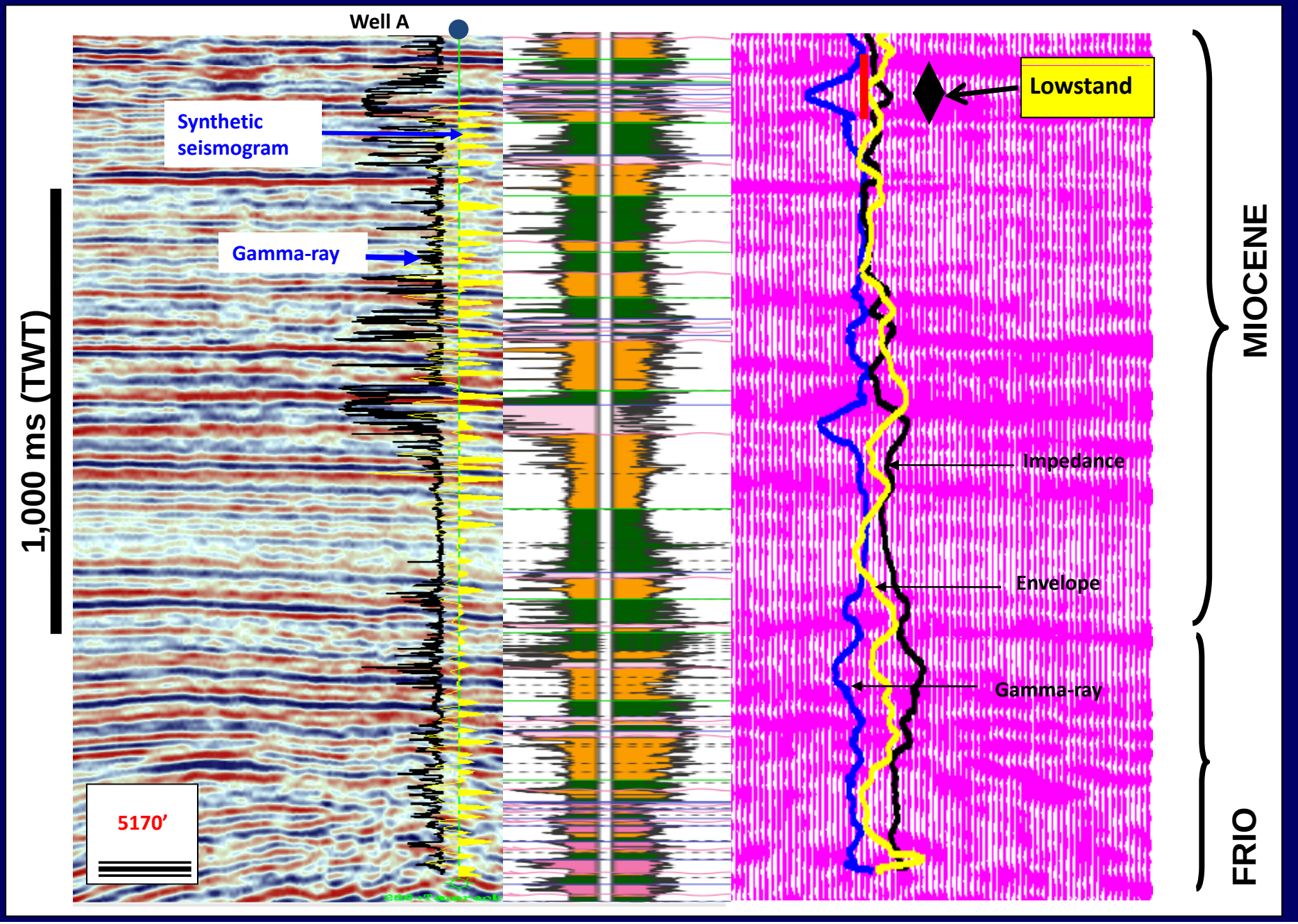
Relating amplitude (amplitude envelope) to lithology: Work flow

- Tie well logs to seismic data
- Generate sequence stratigraphic interpretation identifying the various systems tracts from composite well log and obtain S5 log
- Generate acoustic impedance (AI) log
- Generate amplitude envelope (AE) volume
- Extract AE trace
- Generate cross plots of well logs, AI, and AE within the various systems tracts; obtain best-fit curves; and interpret results

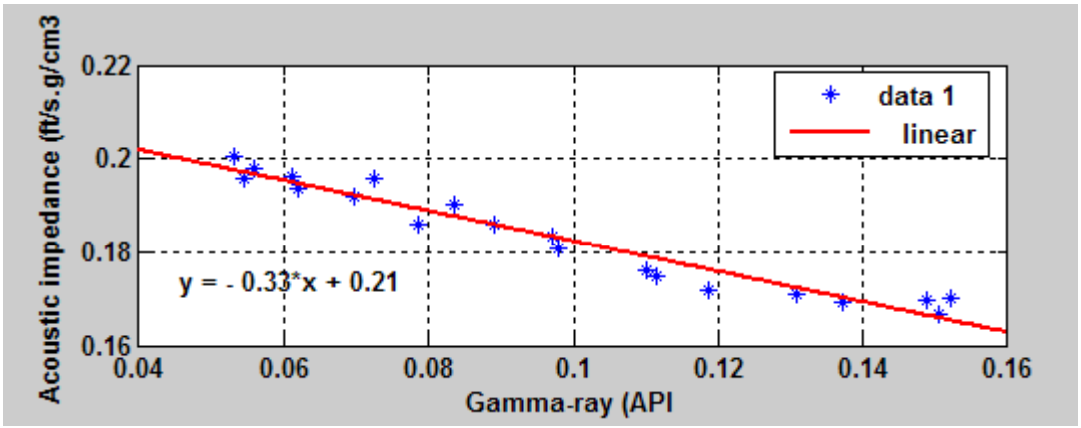
Results from Redfish Bay

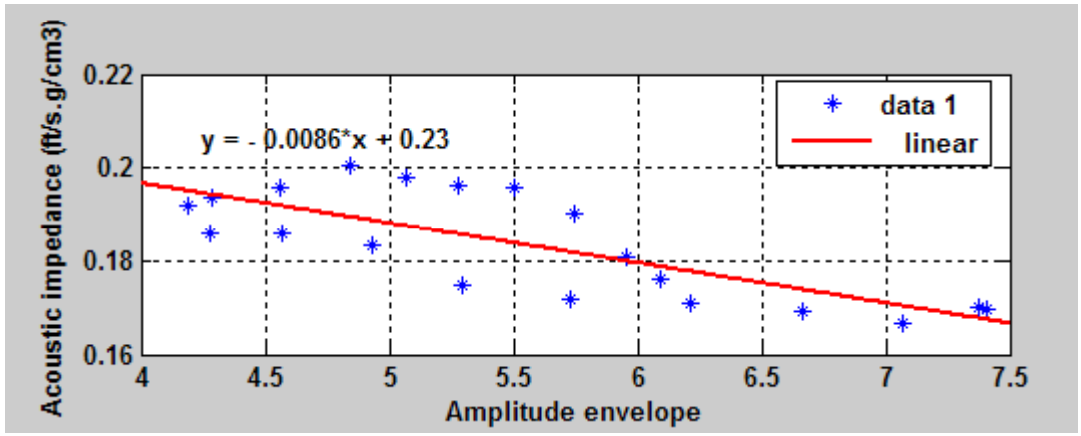
Cross plots within various systems tracts and interpretation—Miocene analysis

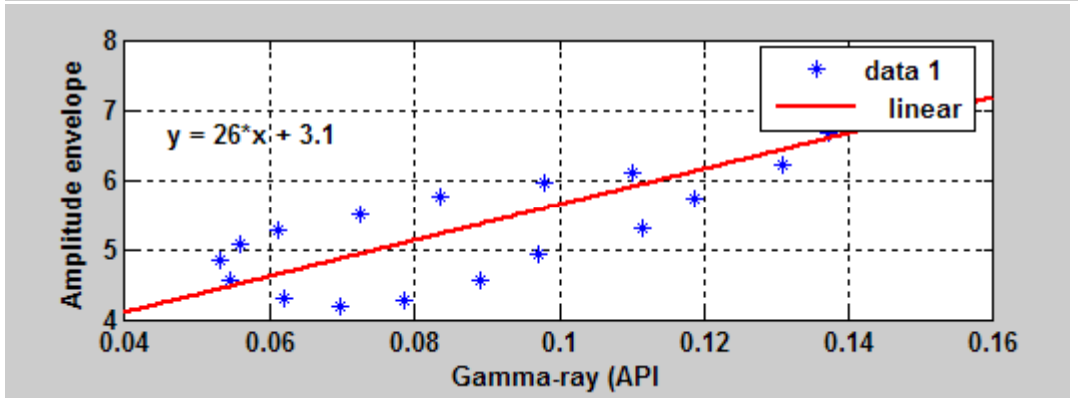
Redfish Bay Miocene lowstand systems tract



Redfish Bay Miocene lowstand systems tract

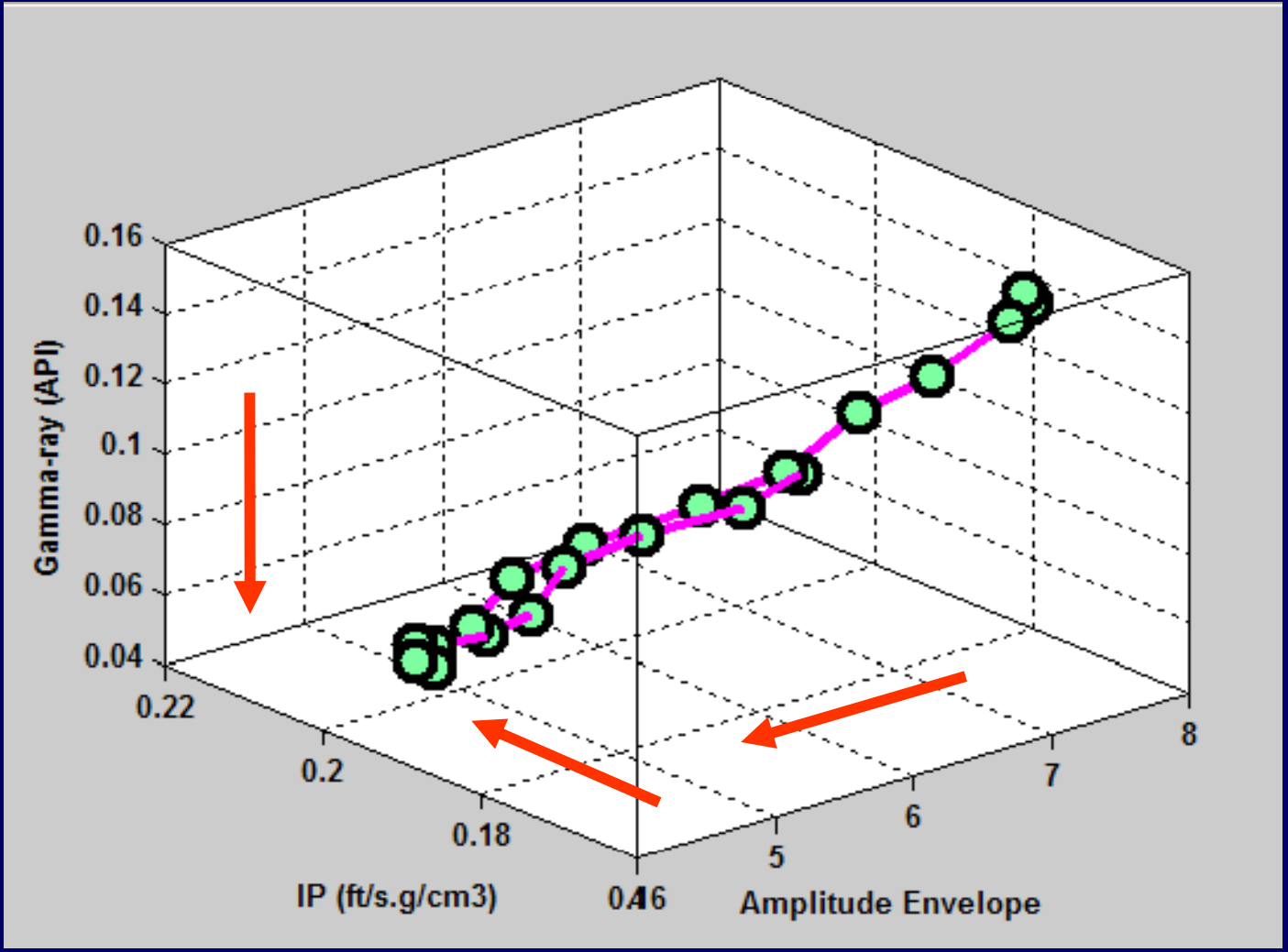






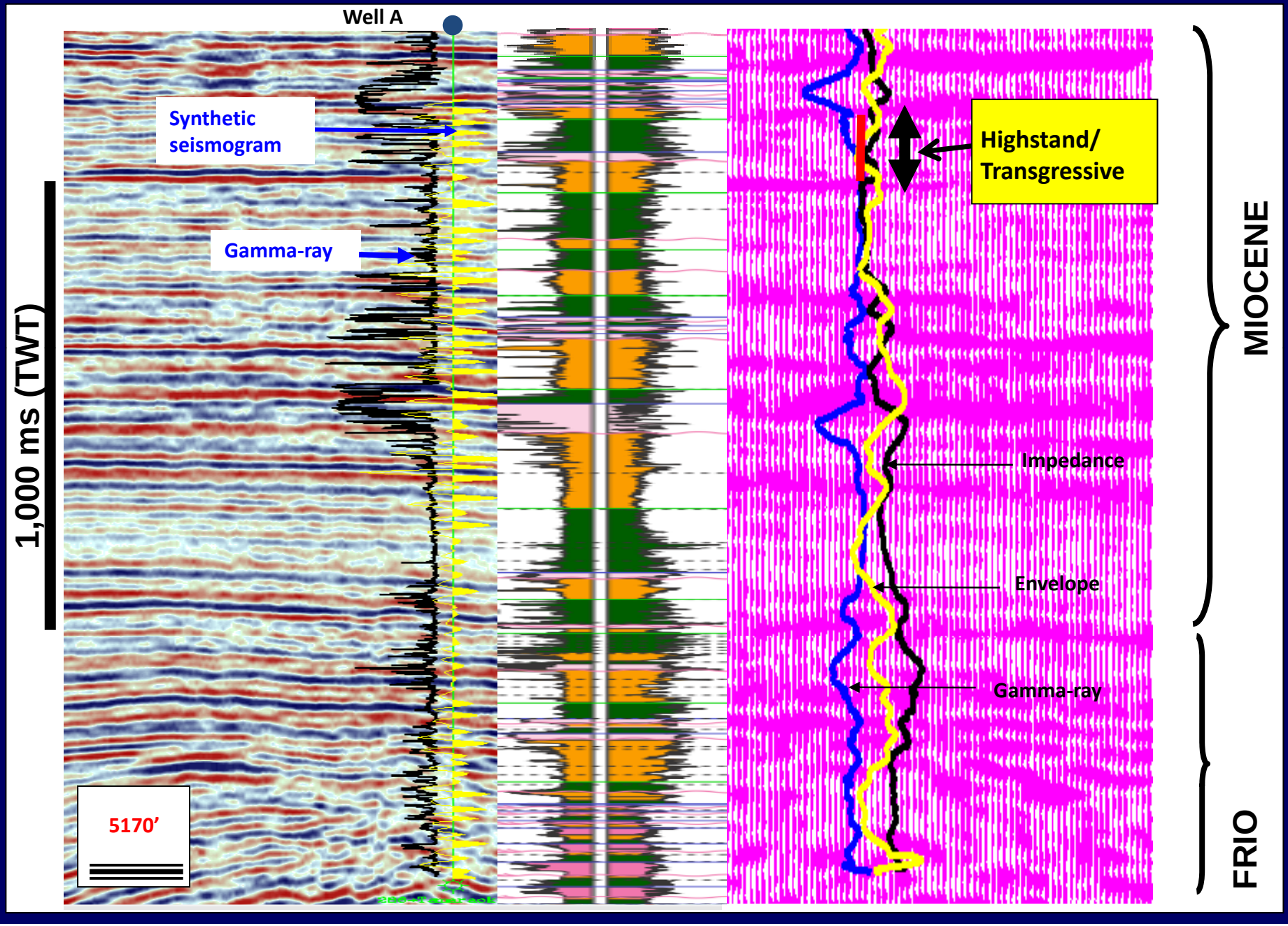
The three curves show linear relationships.
AI vs. gamma-ray and AI vs. AE have similar trends (negative gradients).

Redfish Bay Miocene lowstand systems tract: 3D cross plots of AI, AE, and Gamma-ray

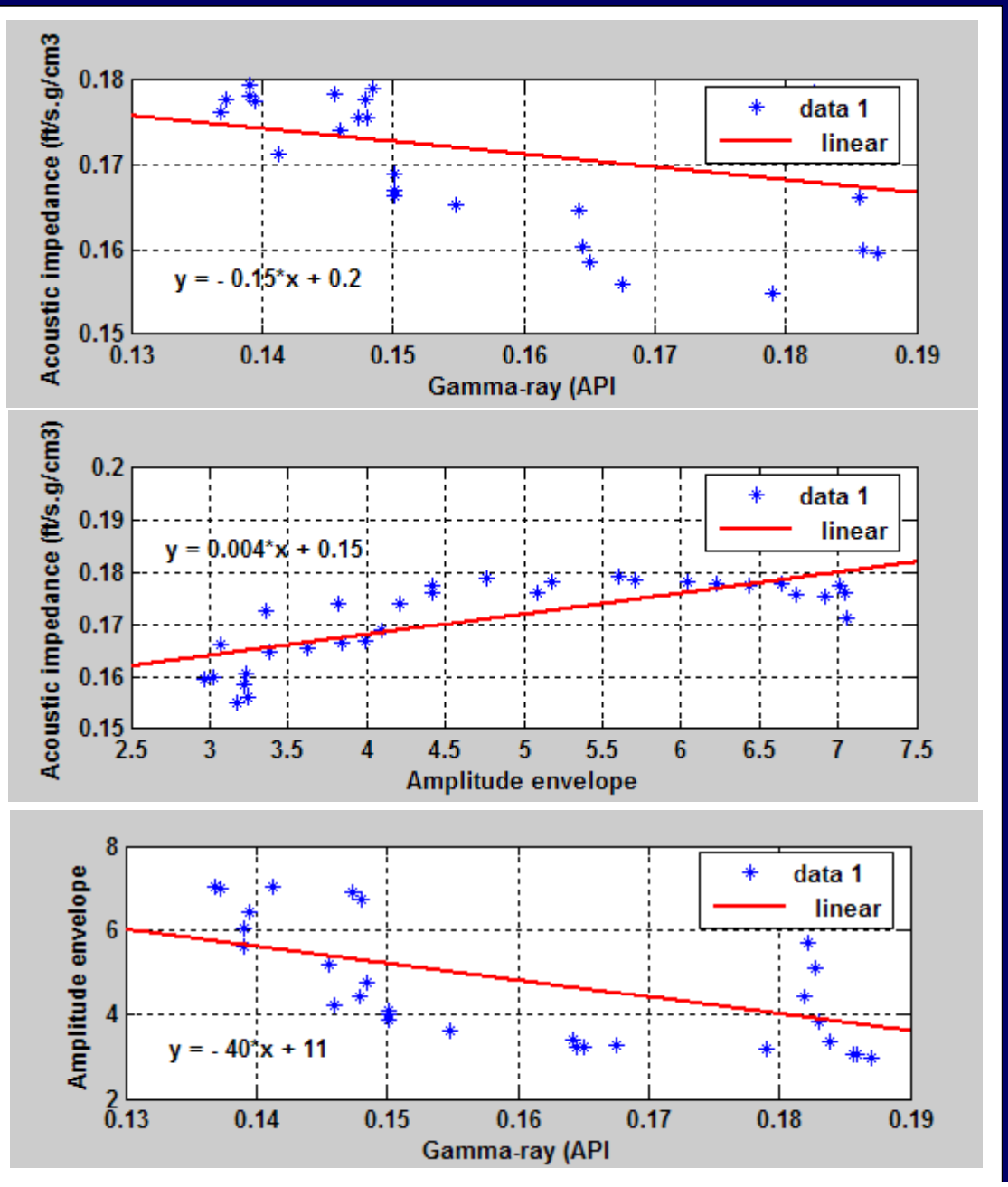


3D plots of gamma-ray as a function of AI and AE. Results show that sand-rich zones increase as AE's decrease and AI's increase.

Redfish Bay Miocene highstand/transgressive systems tracts



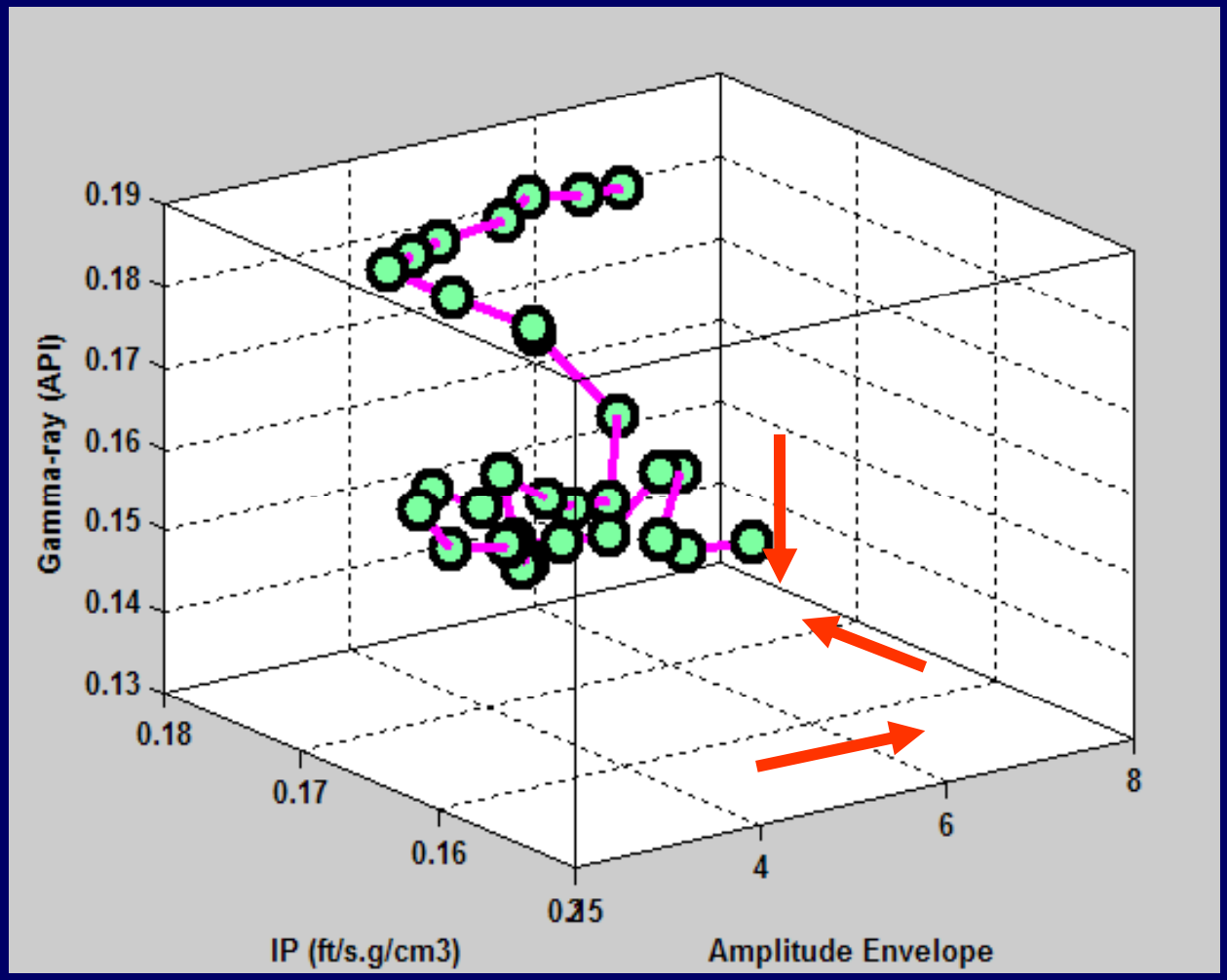
Redfish Bay Miocene highstand/transgressive systems tracts



2D cross plots

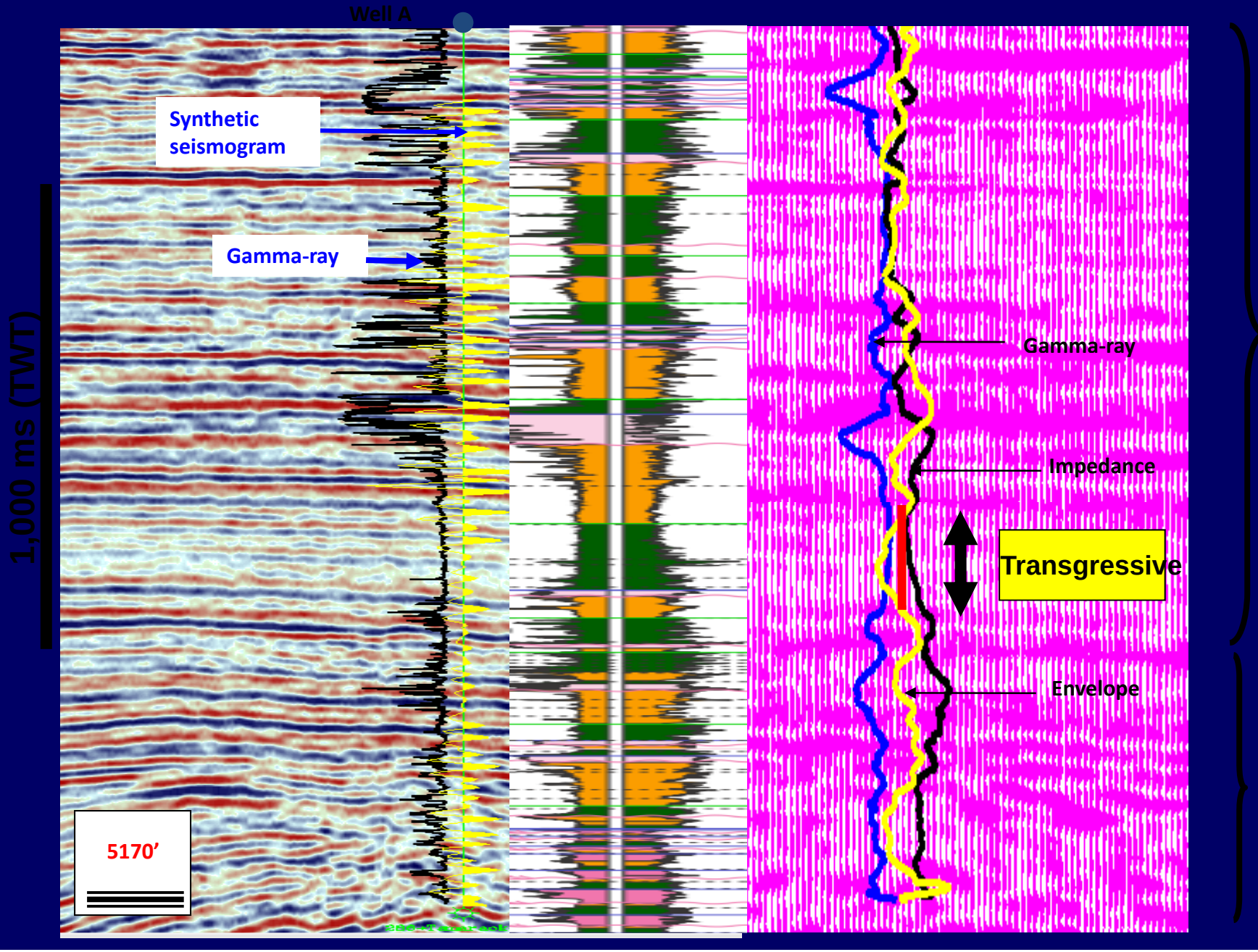
These curves are approximately linear. AI vs. gamma-ray and AI vs. AE have opposite trends (positive and negative gradients), suggesting mixed environments.

Redfish Bay Miocene highstand/transgressive systems tracts: 3D cross plots of AI, AE, and gamma-ray

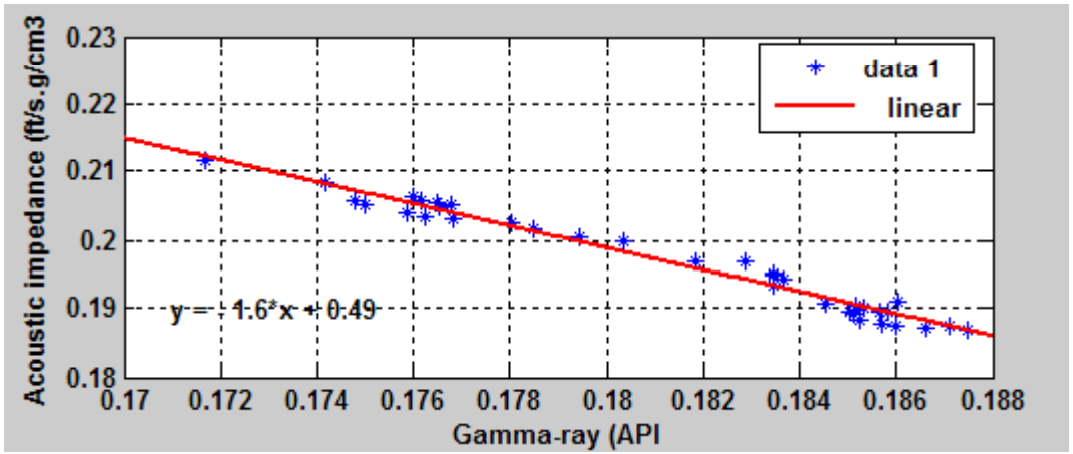


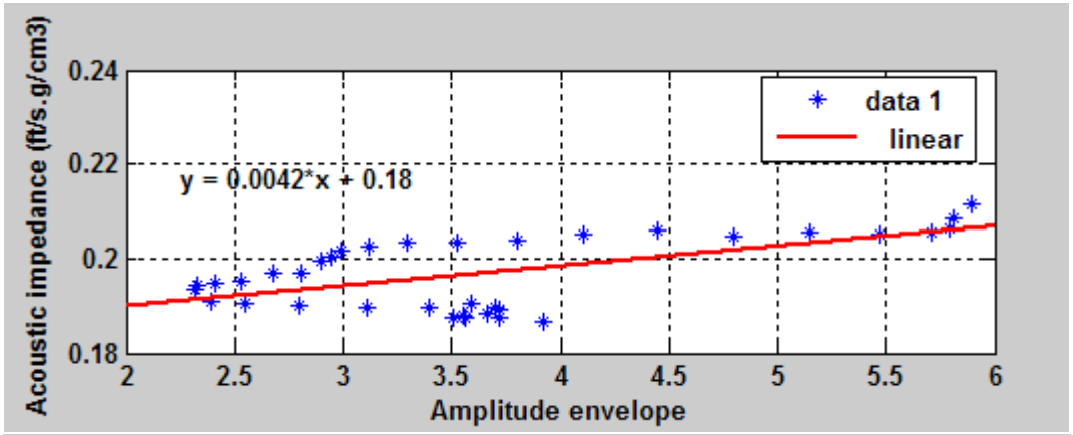
The nature of the curve is not easily interpretable, suggesting a mixed environment. However, high AE's imply low gamma-ray (sand-rich zones).

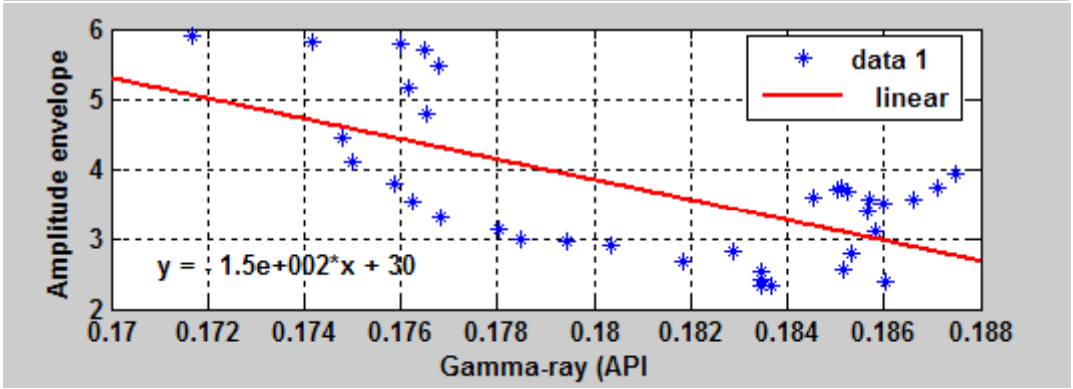
Redfish Bay Miocene Transgressive—Anahuac



Redfish Bay Miocene Transgressive—Anahuac

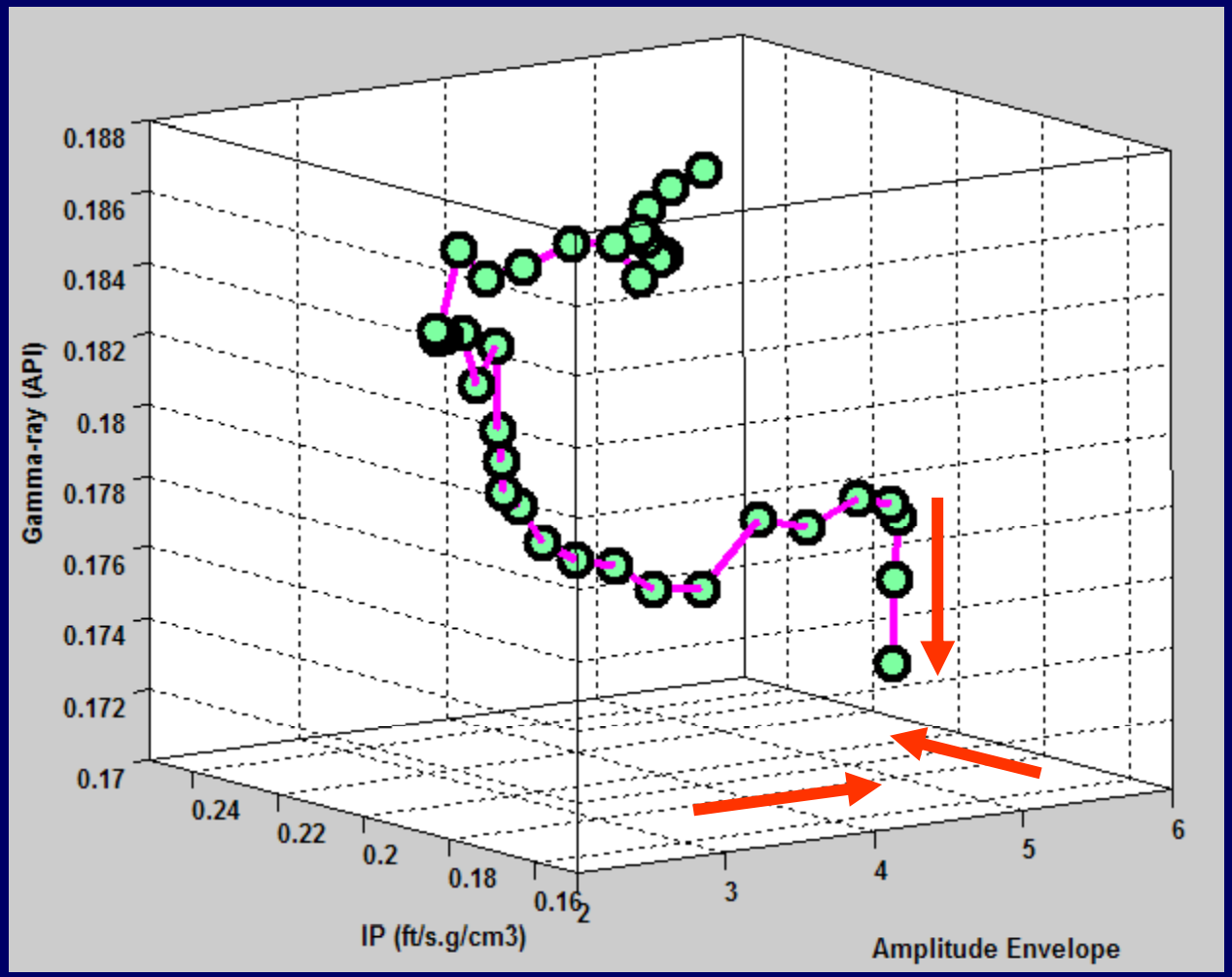






Both AI vs. gamma-ray and AI vs. AE have different equations (positive and negative gradients).

Redfish Bay Miocene Transgressive—Anahuac: 3D cross plots of AI, AE, and Gamma-ray

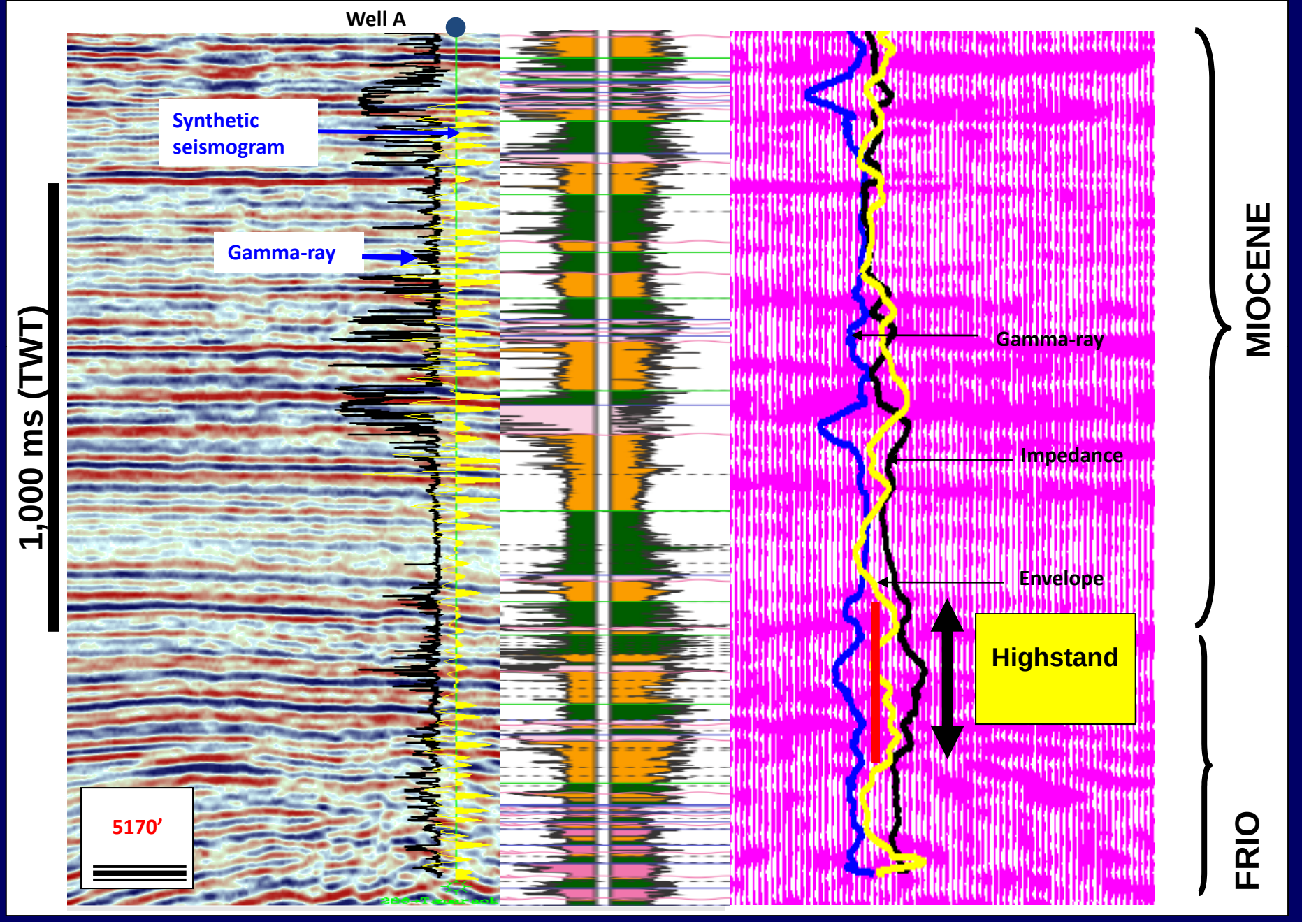


Cross plots show that as AI's and AE's increase, shale content decreases

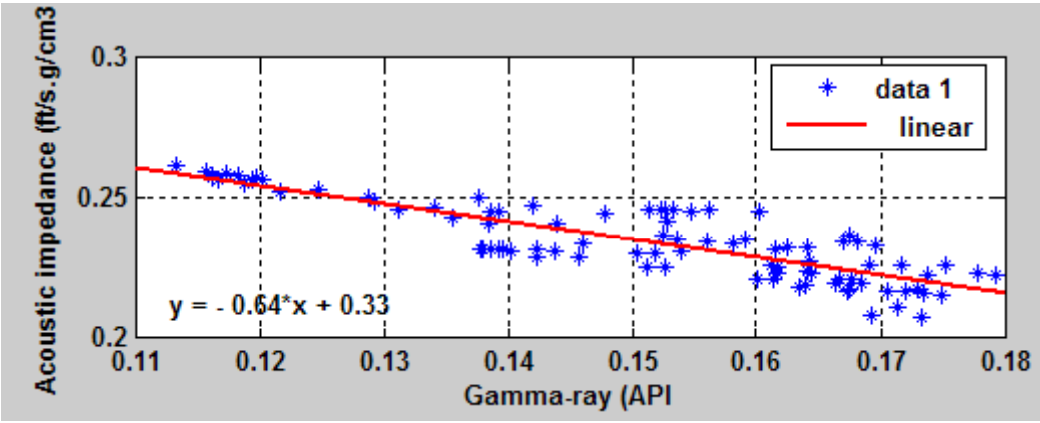
Results from Redfish Bay

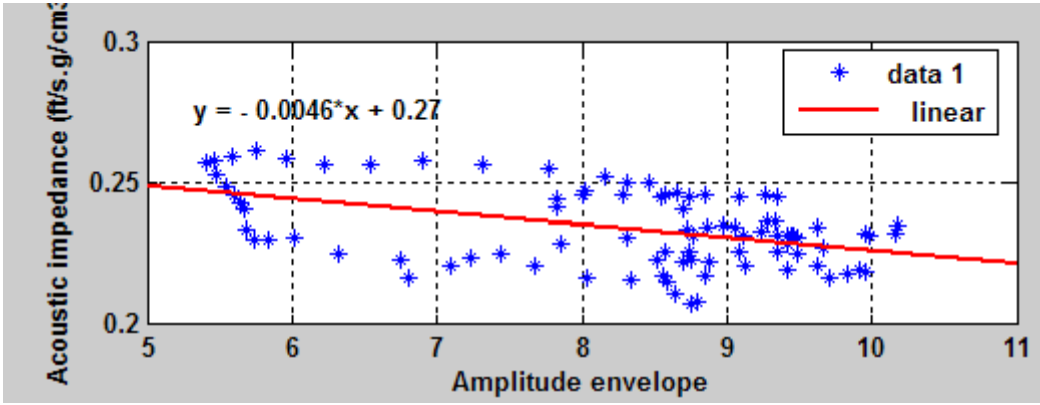
Cross plots within various system tracts and interpretation—Oligocene Frio analysis

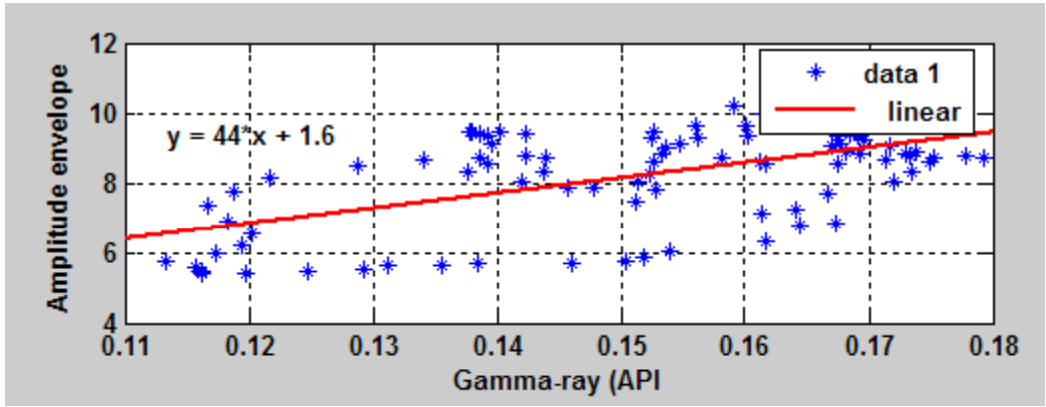
Redfish Bay Oligocene Frio highstand systems tract



Redfish Bay Oligocene Frio highstand systems tract



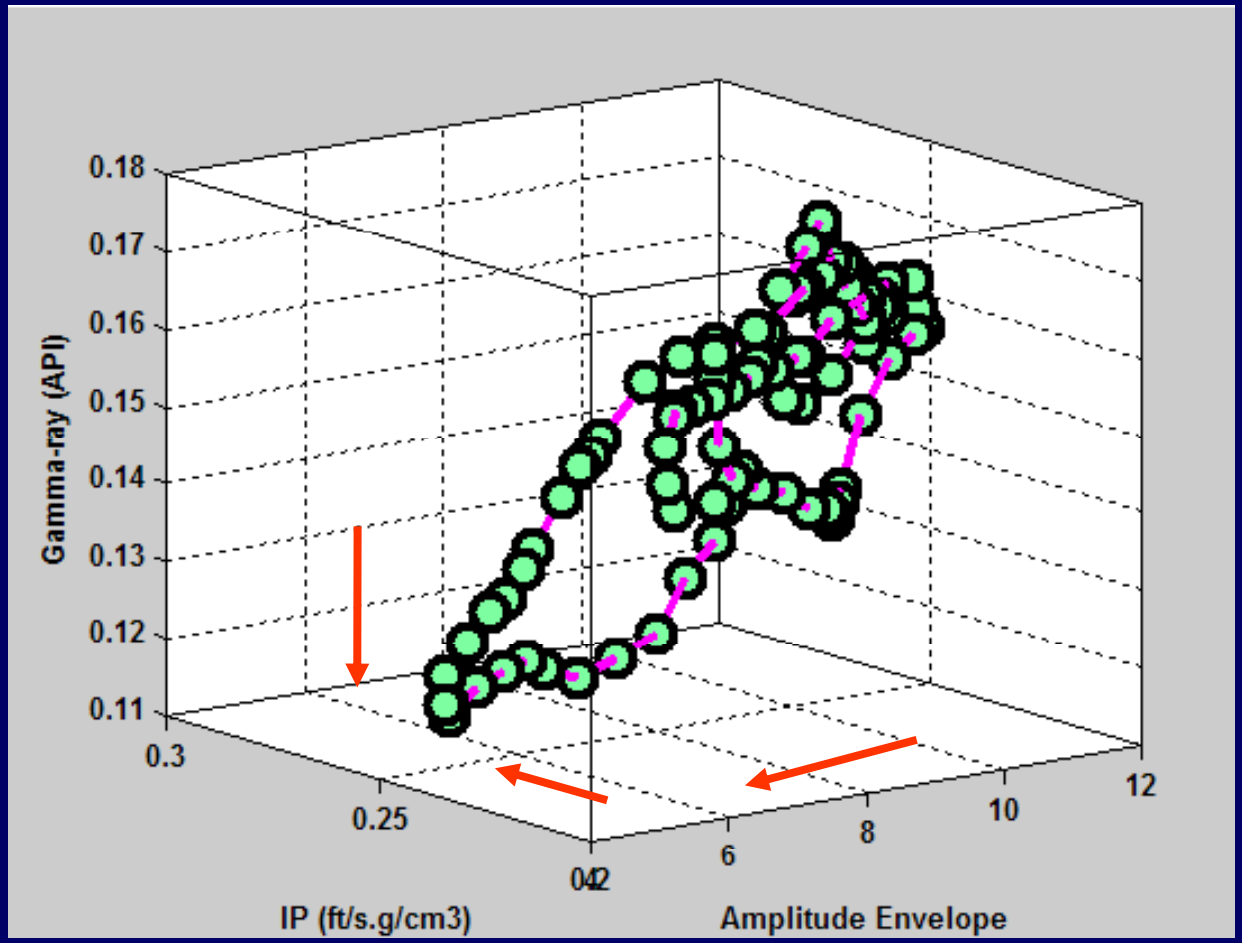




2D cross plots

AI vs. gamma-ray and AI vs. AE curves have similar equations. As AE's decrease, gamma-ray decreases, suggesting sand-rich zones.

Redfish Bay Oligocene Frio highstand systems tract: 3D cross plots of AI, AE, and Gamma-ray

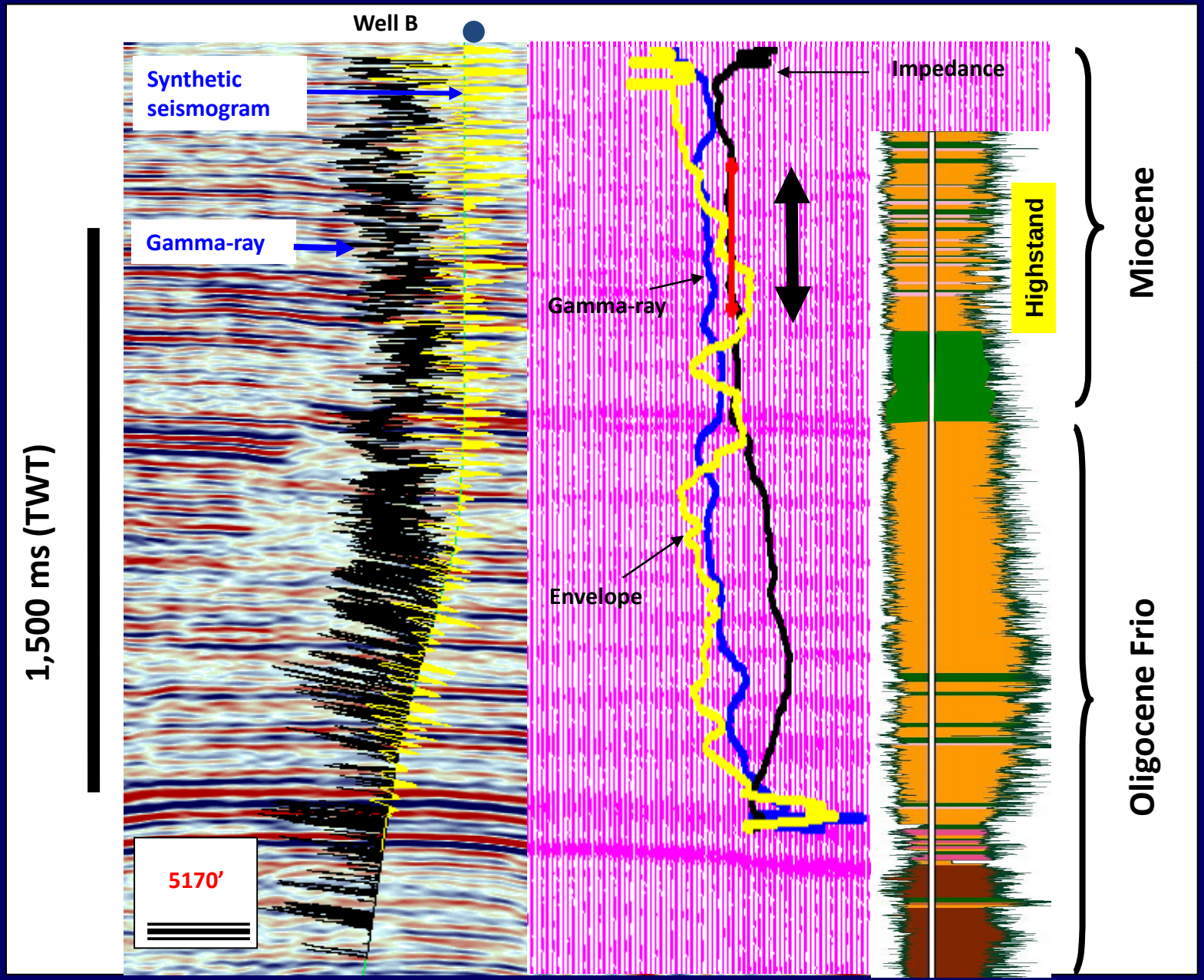


Cross plots show that as AI's increase and AE's decreases, sand content increase suggesting that sand-rich zones are of low energy.

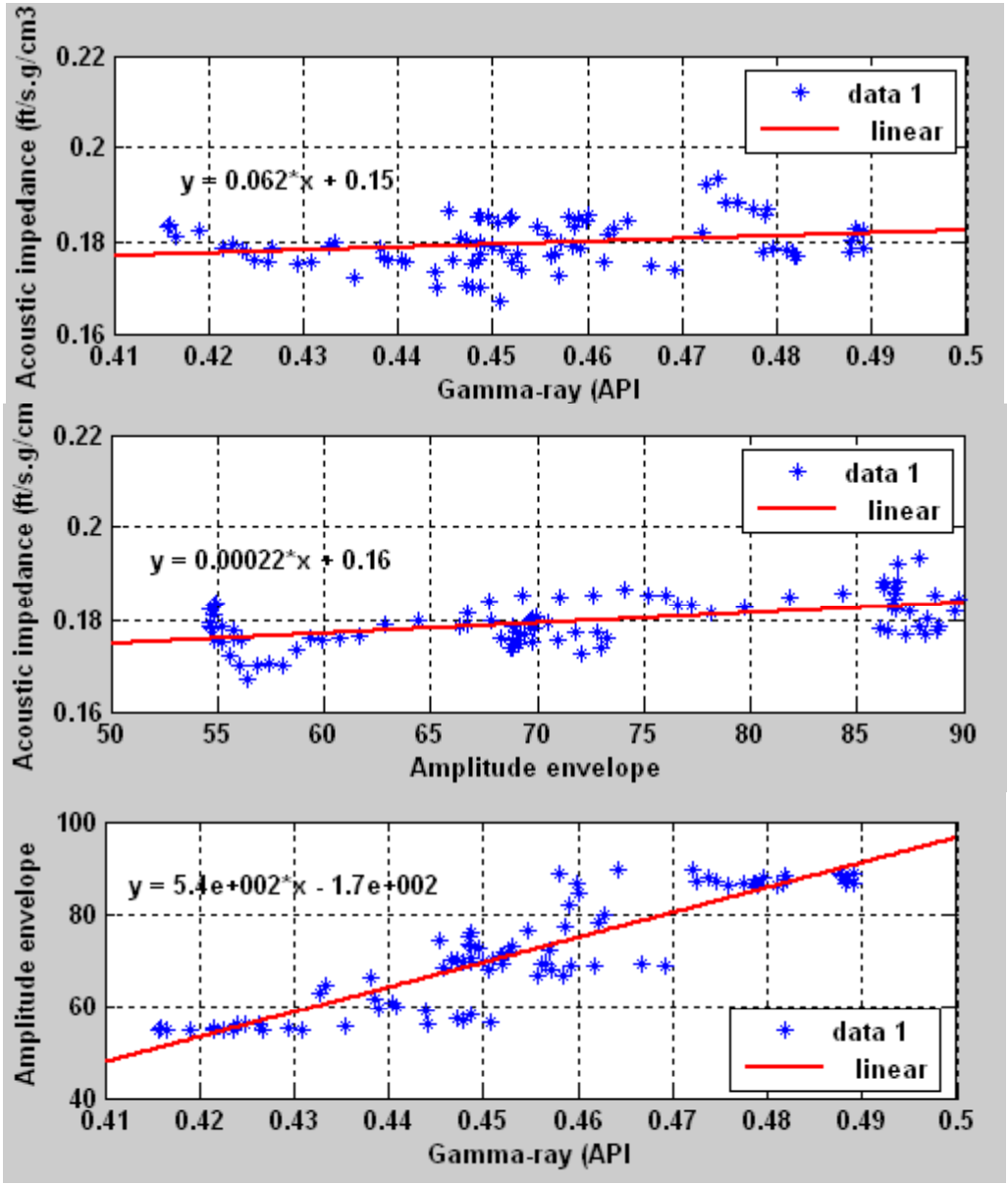
Results from Laguna Madre basin:

Cross plots within various systems tracts and interpretation

Laguna Madre Miocene highstand systems tract



Laguna Madre Miocene highstand systems tract



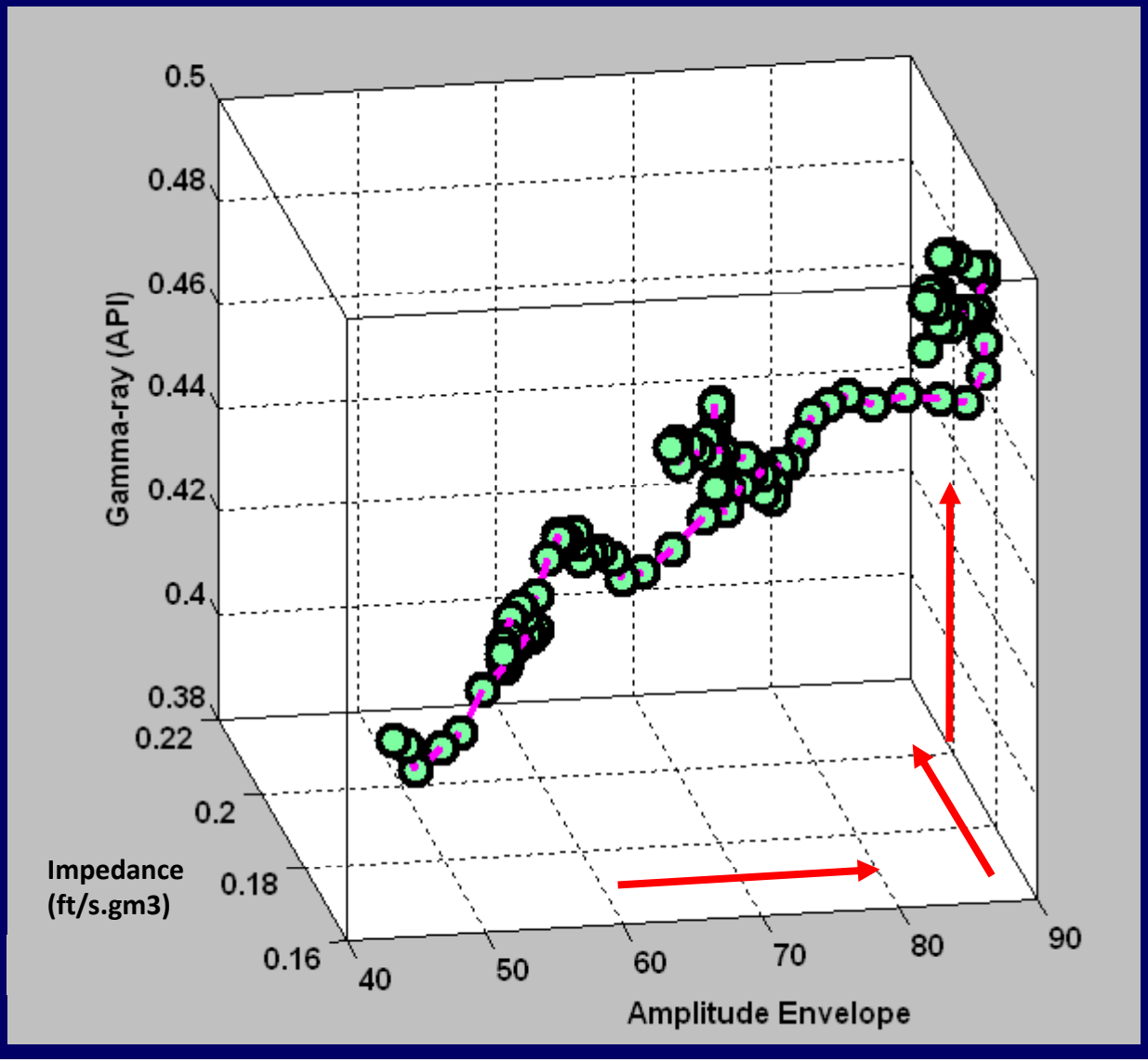
2D cross plots

Increasing AI's and AE's suggest high gamma-ray (shale-rich zones).

AI vs. gamma- ray and AI vs. AE plots have similar equations with positive gradients.

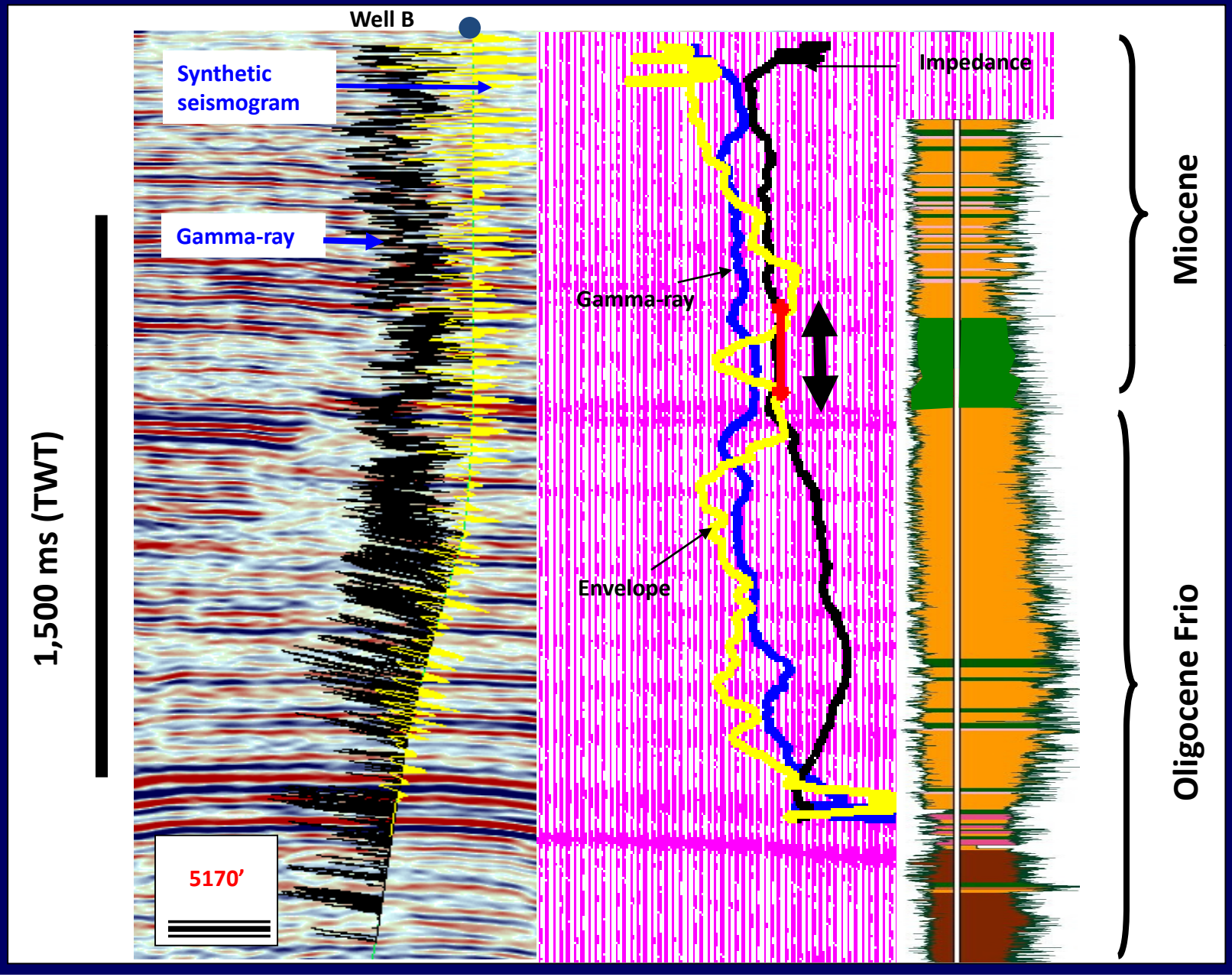
The interval does not contain any significant lowstand.

Laguna Madre Miocene highstand systems tract: 3D cross plots of AI, AE and Gamma-ray

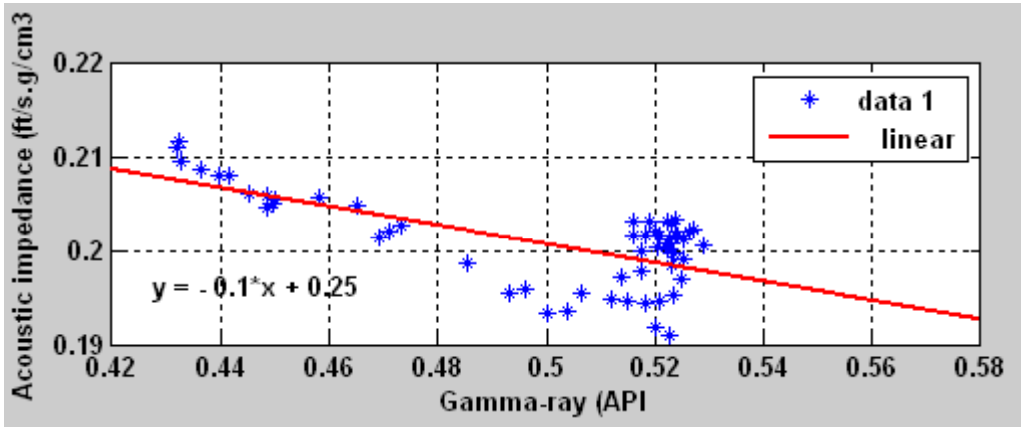


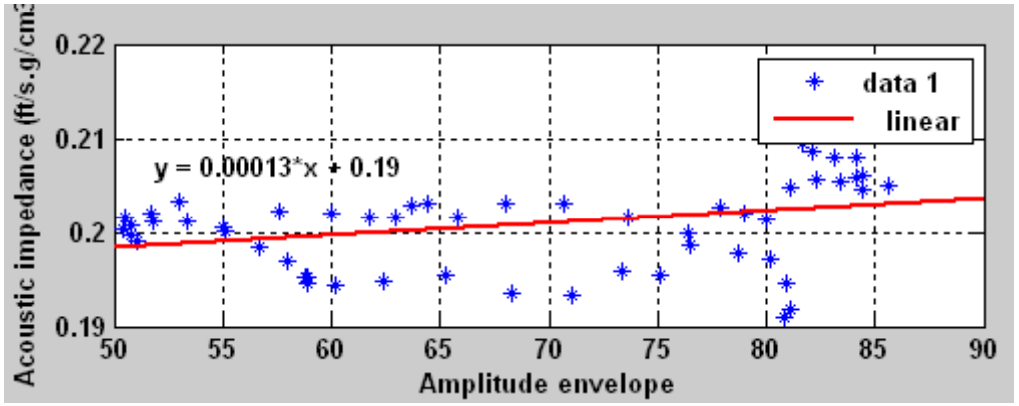
3D plots showing gamma-ray values as AI and AE vary. In highstand system tracts, high AE's values suggest shale-rich zones

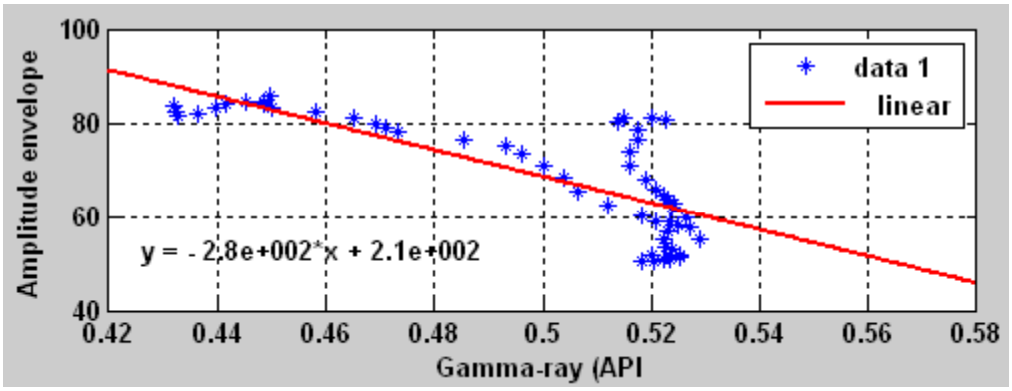
Laguna Madre Miocene transgressive—Anahuac



Laguna Madre Miocene transgressive—Anahuac

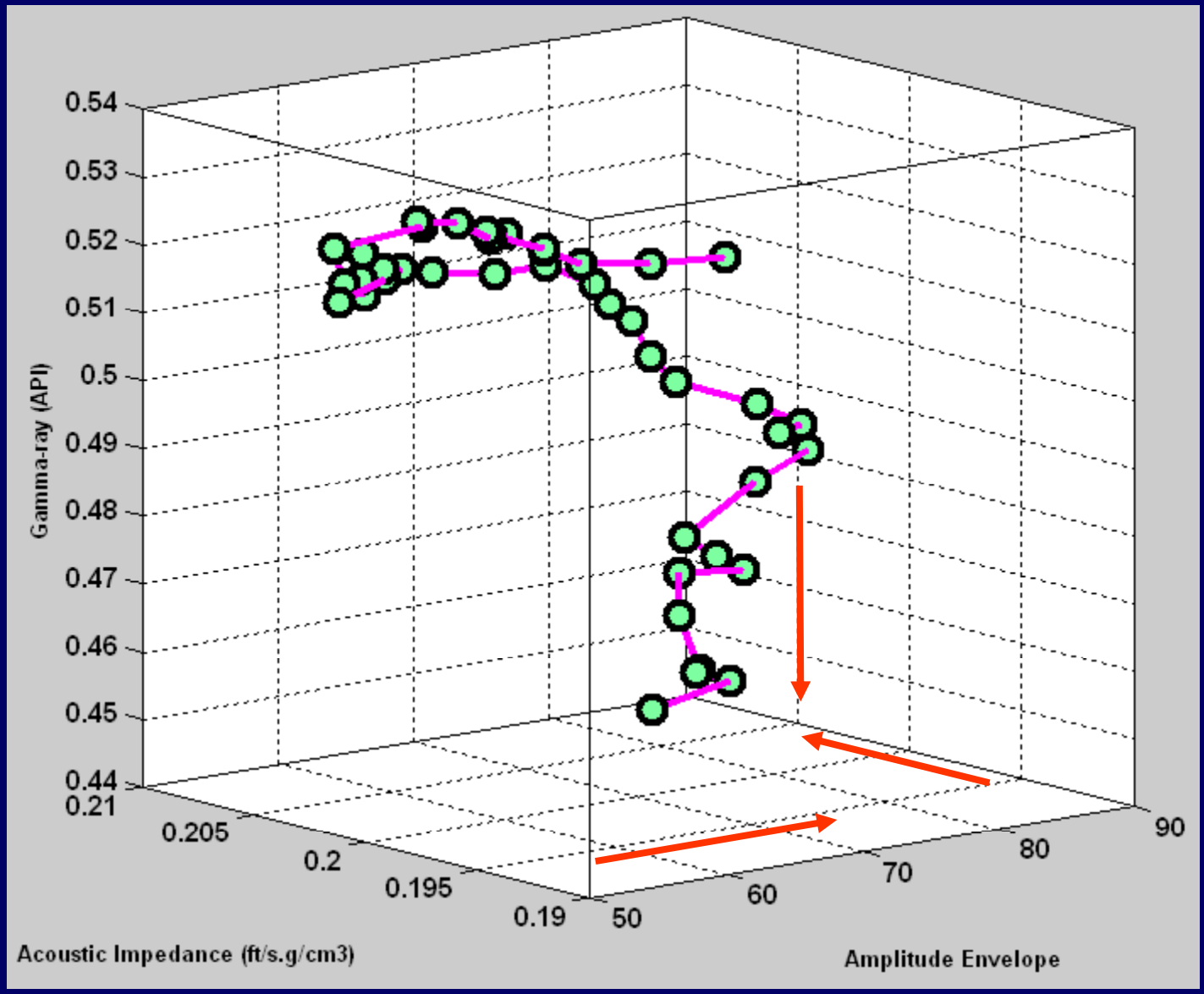






The three curves show approximately linear relationships.
Both AI vs. gamma-ray and AI vs. AE have different trends.

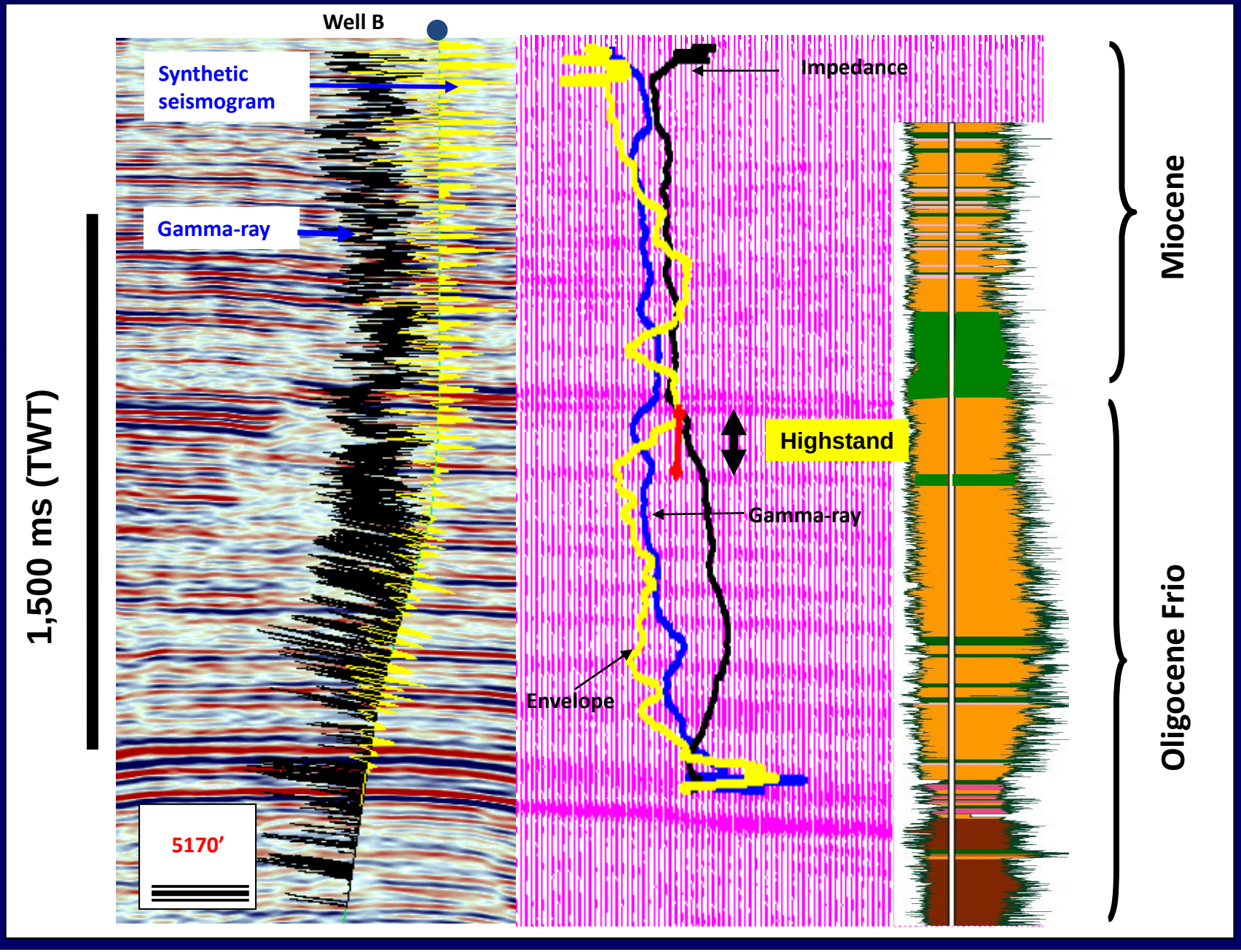
Laguna Madre Miocene transgressive—Anahuac: 3D cross plots of AI, AE, and Gamma-ray



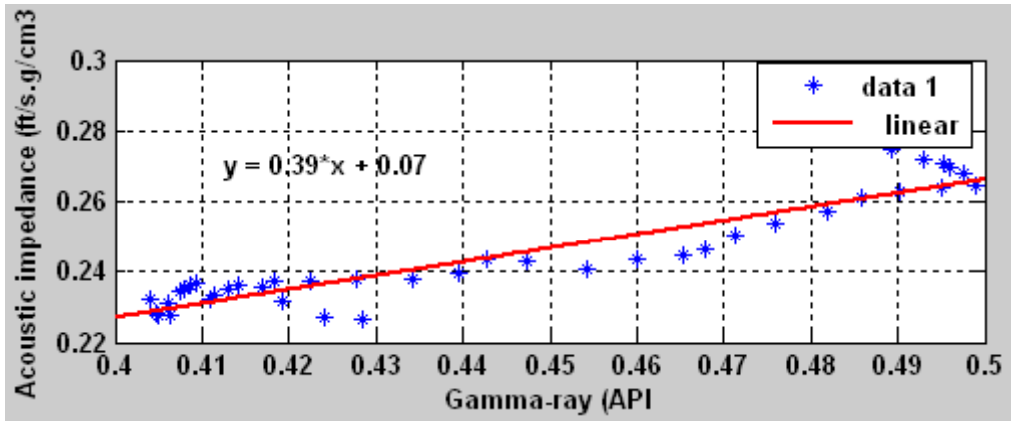
In transgressive system tracts, low AE's and high AI's imply shale-rich zones; i.e., high AE's and low AI's, imply sand-rich zones such as turbidites.

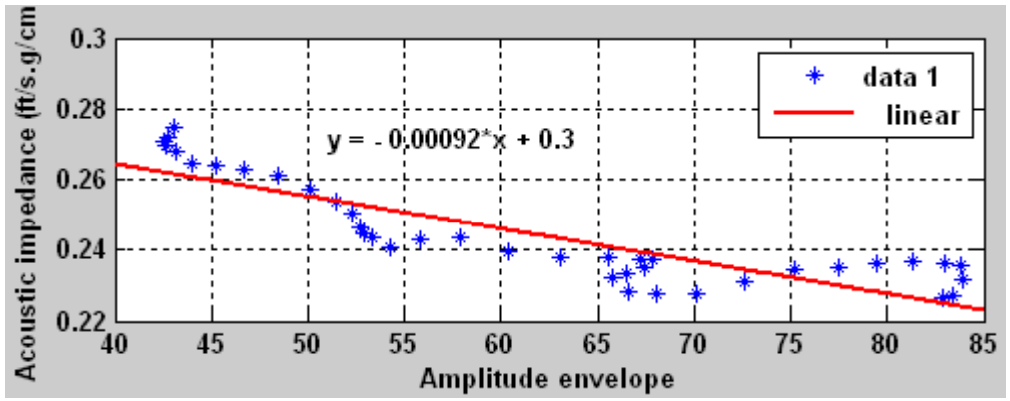
Trend is similar to the Anahuac in Redfish Bay.

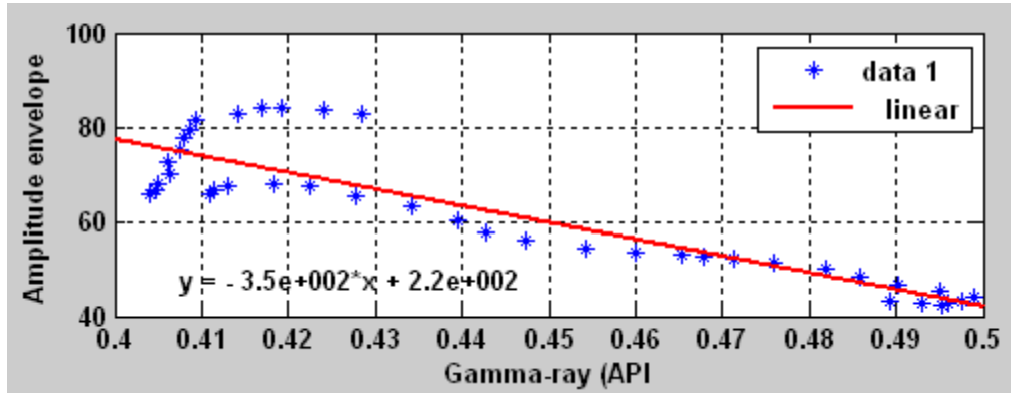
Laguna Madre Oligocene Frio highstand systems tract



Laguna Madre Oligocene Frio highstand systems tract



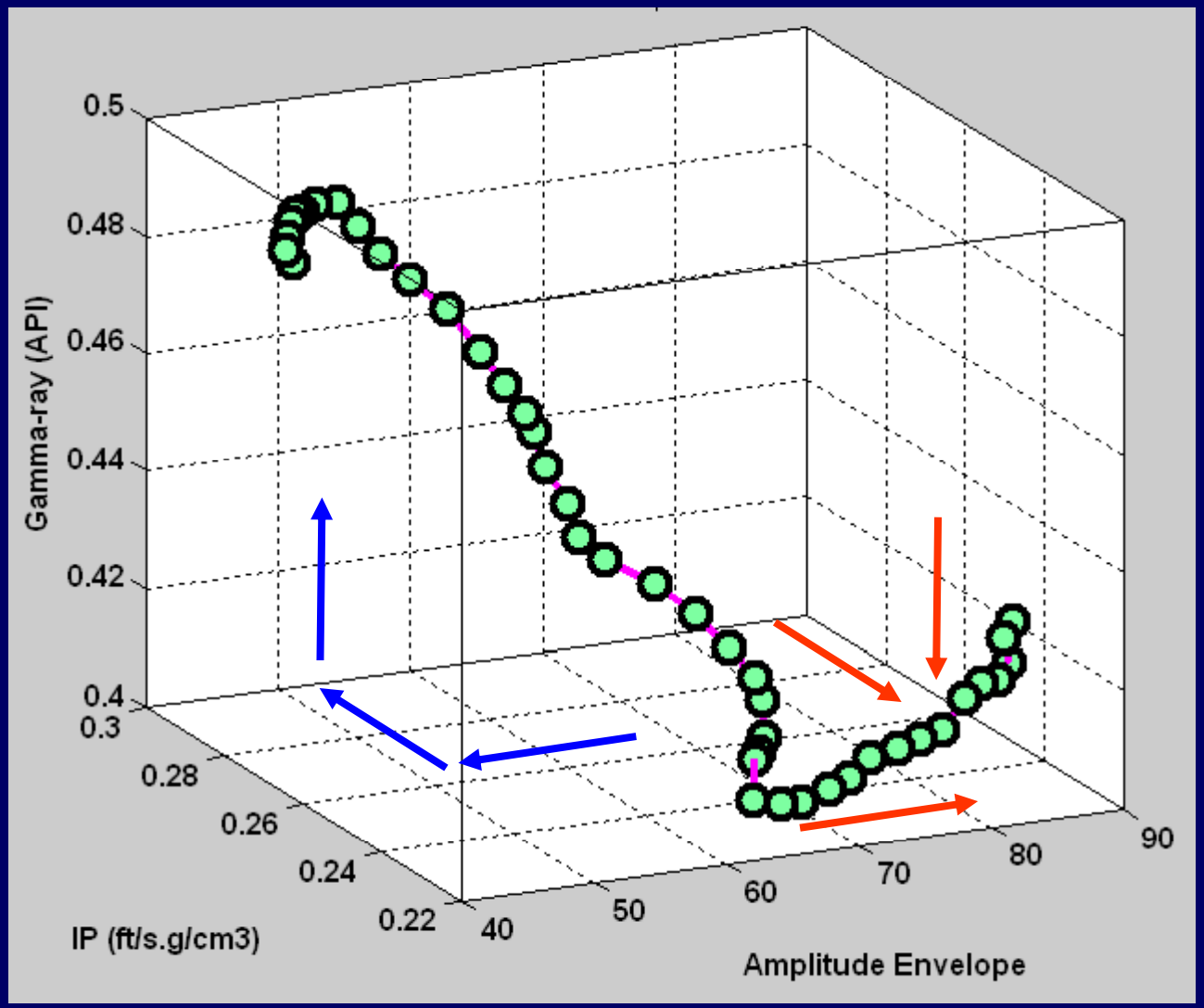




2D cross plots

Graphs show that high AE's low AI's suggest sand-rich zones. Results are contrary to what is observed in Redfish Bay. Plot of AI vs gamma-ray shows a different trend (positive gradient)– Impedance increases as shale content increases.

Laguna Madre Oligocene Frio highstand systems tract: 3D cross plots of AI, AE and Gamma-ray



Cross plots show that high AE's and low AI's suggest sand-rich zones. Results are contrary to what is observed in Redfish Bay.

CONCLUSIONS

- **Miocene highstand:**
  In Redfish Bay, high acoustic impedance and high amplitude envelope suggest sand-rich zone, whereas in Laguna Madre, high acoustic impedance and high amplitude envelope suggest shale, implying different local sediment supply, diagenesis, etc, in the two subbasins.

- **Miocene transgressive Anahuac:**
  In both Redfish Bay and Laguna Madre, high impedance and high amplitude envelope suggest sand-rich zones (turbidites), implying a widespread event common to both subbasins

  In Redfish Bay lowstand incised-valley-fills, sand-rich zones are characterized by high impedance and low amplitude envelope.

- **Oligocene highstand:**
  In Redfish Bay, high impedance but low amplitude envelope suggest sand-rich zones, whereas in Laguna Madre, high impedance but low envelope suggest shales, implying different local sediment supply, diagenesis, etc. in the two subbasins.

- **In deriving linear relationships between amplitude envelope and gamma-ray and between impedance and amplitude envelope, analysis should be performed within each systems tract to avoid ambiguous interpretation.**

- **Linear relationships between these variables in the various systems tracts can vary from subbasin to subbasin. As such, relationships established in one subbasin may not apply in another subbasin.**

ACKNOWLEDGMENTS

- LANDMARK GRAPHICS
- WESTERN GECO
- Project STARR

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