Imaging Techniques in Seismic Geomorphology*

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Abstract

Pattern recognition has long been a key to our understanding of geologic landforms and depositional regimes. Channels, dunes, reefs, debris flows, and karst regions all exhibit various geomorphic patterns that provide insight into their origins. In fact, much of the success or failure associated with a geologic investigation depends on our ability to identify and classify various depositional and/or erosional patterns. For the geophysicist interested in reconstructing ancient landforms hidden within his or her 3D seismic amplitude data, there are many challenges that need to be addressed in order to accurately image the associated patterns. To begin with, the frequency content of traditional seismic data may not be appropriate for resolving certain geologic features. Subtle lithologic changes are not always apparent to the interpreter using traditional seismic data. And variably dipping seismic reflectors can often obscure the original depositional patterns required for in-depth analysis.

The purpose of this discussion is to highlight and discuss various imaging techniques in seismic geomorphology. Many different seismic attributes and spectral decomposition techniques are often able to enhance and bring out subtle features and/or lithologic changes that are still hidden within a traditional seismic amplitude display. Flattening and various slicing techniques can be used to help unravel complexities related to non-uniform horizons. Volume co-rendering of differing attributes can provide additional insights as compared to a single attribute. And finally, voxel body picking allows the interpreter to focus in on a specific range of attribute values which are useful in defining geobodies.

References Cited

Posamentier, H.W., 2005, Application of 3D seismic visualization techniques for seismic stratigraphy, seismic geomorphology and depositional systems analysis: examples from fluvial to deep-marine depositional environments: Petroleum Geology: North-West Europe and Global Perspectives – Proceedings of the 6th Petroleum Geology Conference, p.1565-1576.

Posamentier, H.W., 2000, Seismic stratigraphy into the next millennium; a focus on 3D seismic data: AAPG Annual Convention, New Orleans, LA, April 16-19, 2000, A118.

Imaging Techniques in Seismic Geomorphology

RMS AAPG
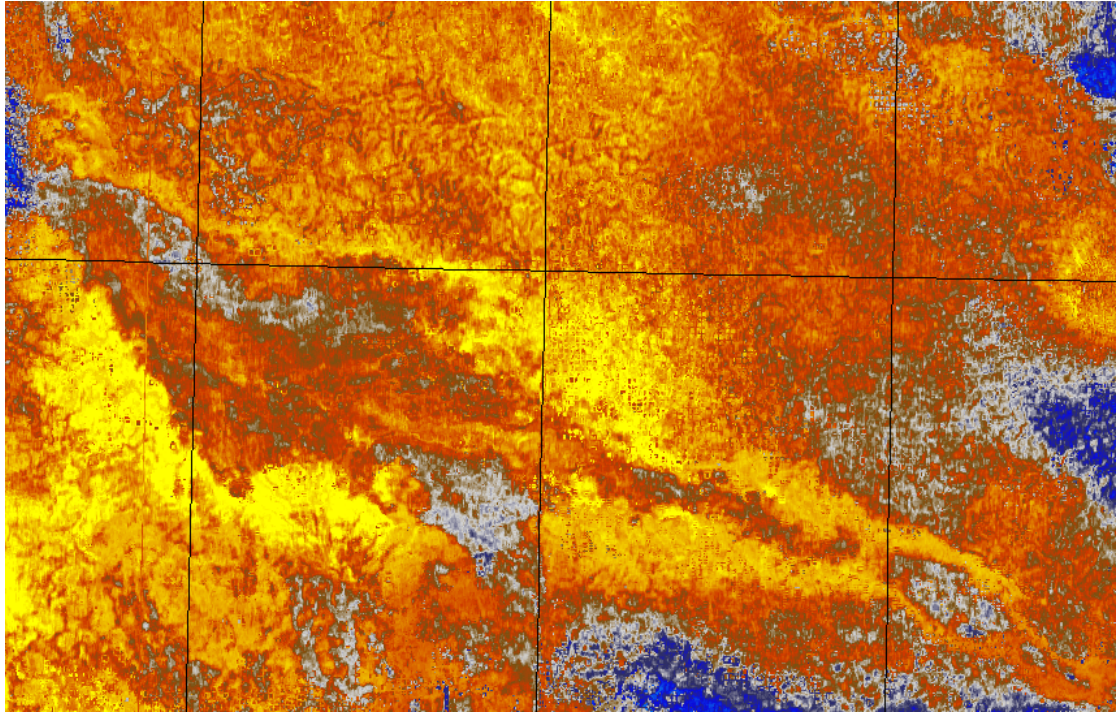
Jim Bock, **jim.bock@ihsmarkit.com**

Vladimir Rybakov, vladimir.rybakov@ihsmarkit.com

Seismic Geomorphology

- **Study of buried landforms and depositional features using various 3D seismic imaging techniques.**

- **Imaging techniques focus on identifying "FLTs"**

  - **Amplitude anomalies**

  - **Linear features**

  - **Geologic**

**Submarine fan system with turbidite channels, Forties Field, North Sea**

Common imaging techniques

- **Horizon attributes**
- **Interval attributes**
- **Seismic attributes**
- **Time and horizon slicing**
- **Perspective rendering**
- **Opacity rendering**
- **Voxbody interpretation**
- **Color Bar selection/animation**
- **Pseudo cube and RGB blending**

Horizon Attributes

- **Examination of horizon reflections using a variety of attributes**

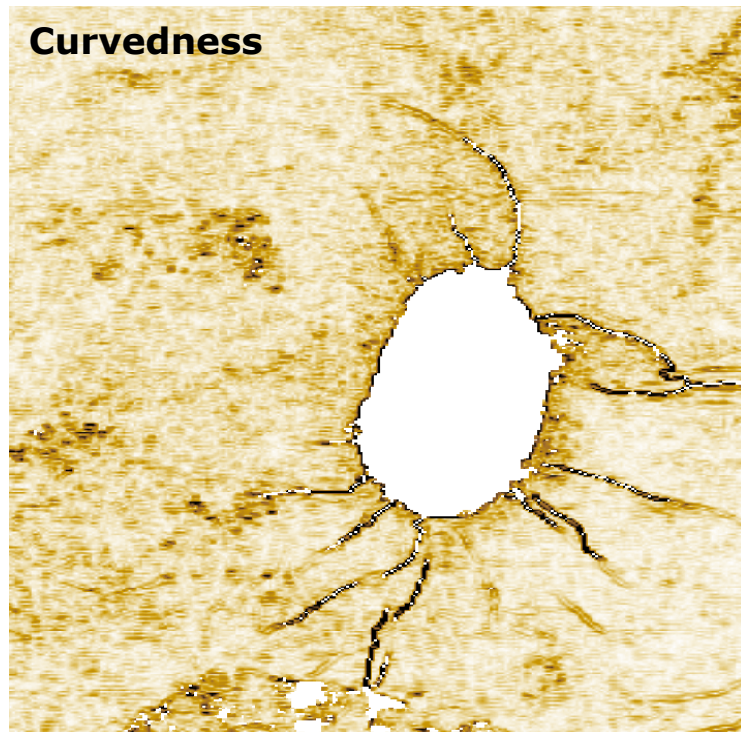- **Reveal different geologic characteristics of feature of interest**

- **Predict lithology**
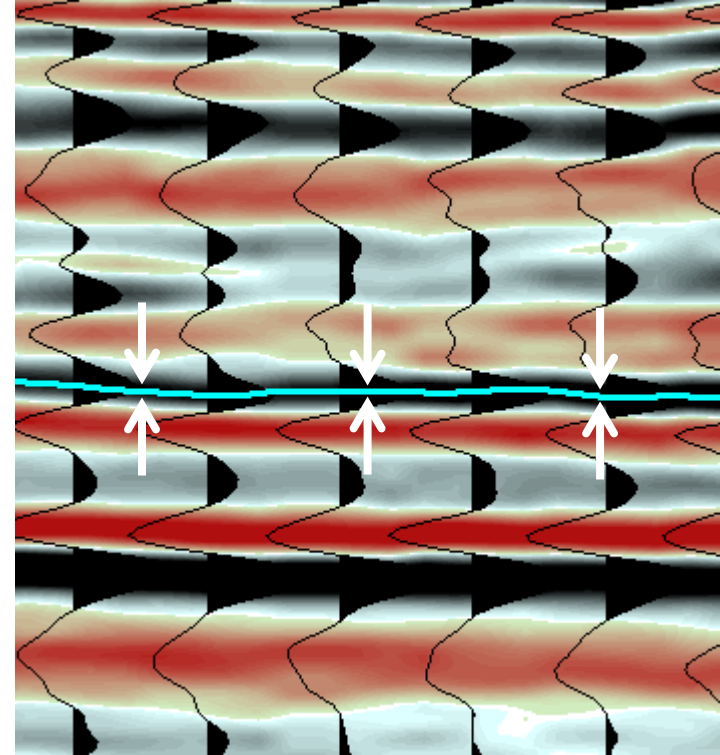
Horizon Attributes

Salt Dome, Gulf of Mexico
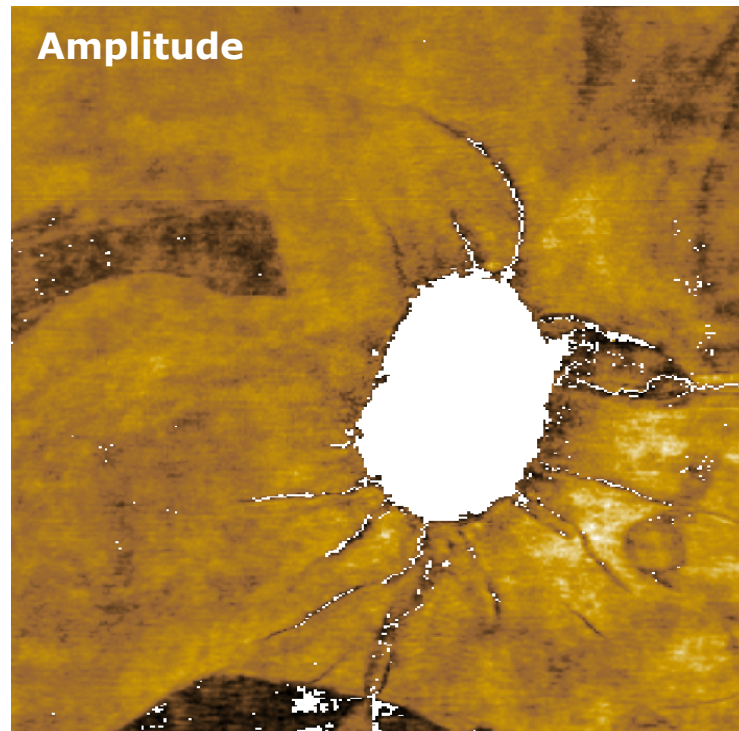

Azimuth of Max Curvature
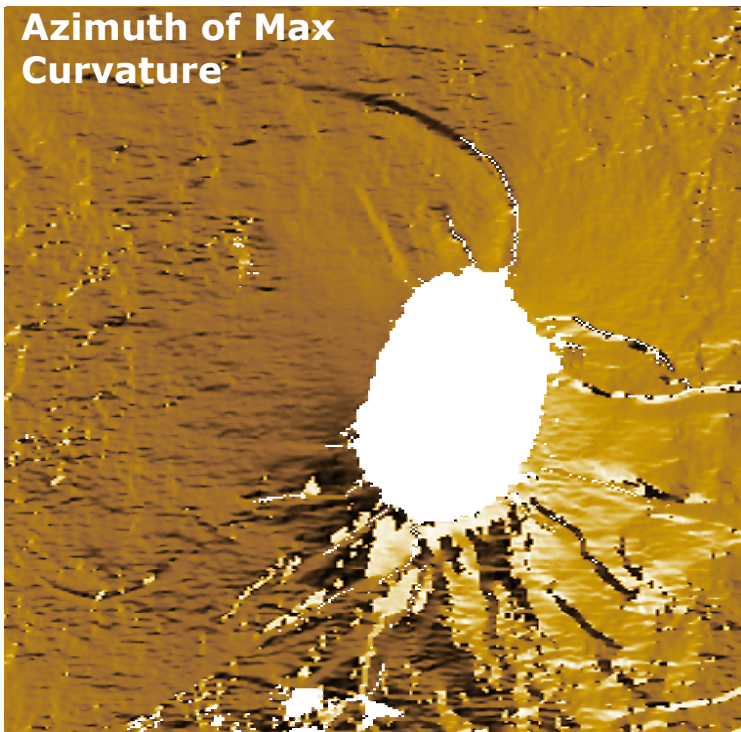
Curvedness

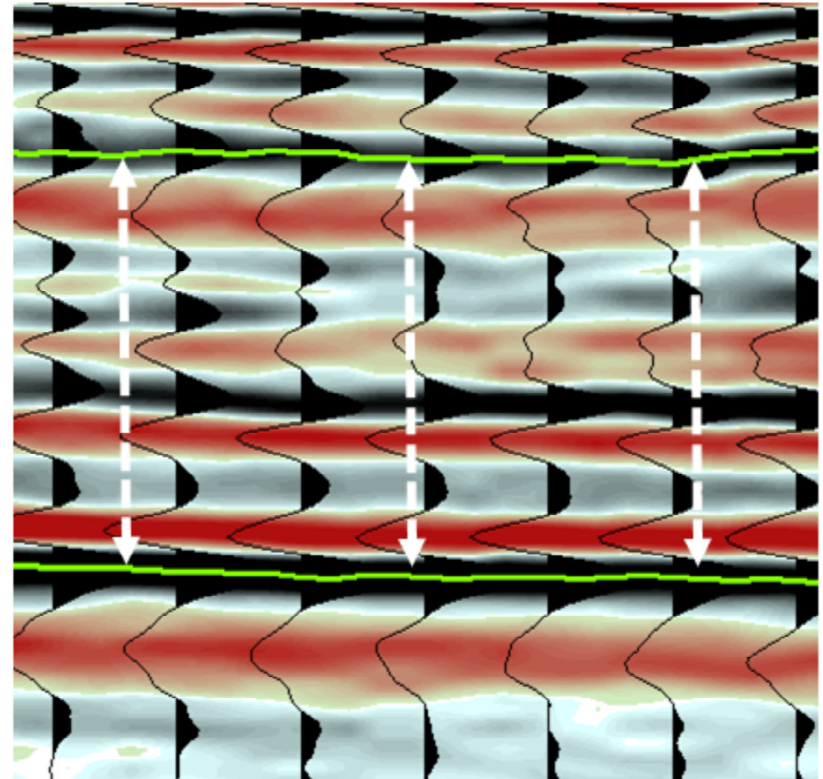# Horizon Attributes

Salt Dome, Gulf of Mexico

Frequency
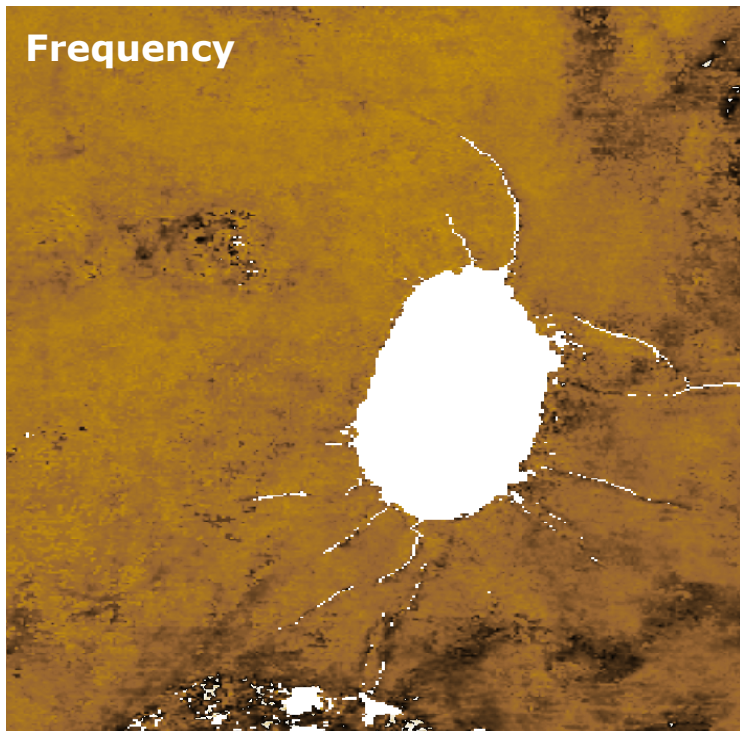
Amplitude

Interval Attributes

- Analysis of a stratigraphic slab (interval).

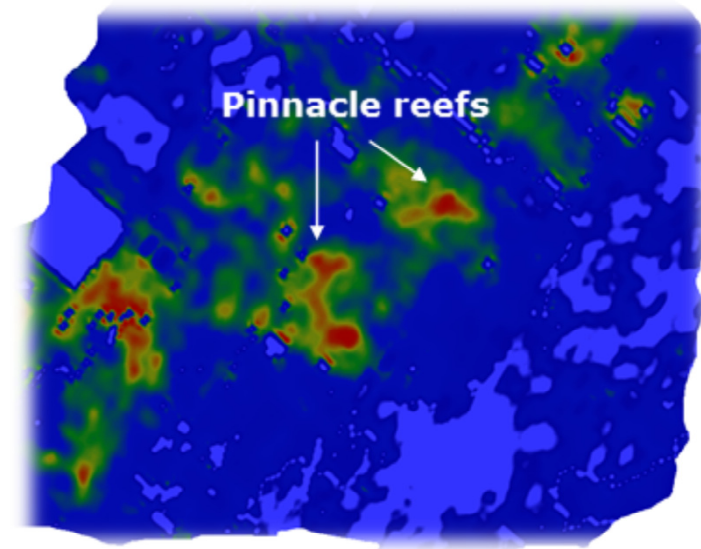- Good for Subtle features that are difficult to interpret/pick

Presenter's notes: Attributes may include amplitude, frequency, zero crossings, number of samples within an specified amplitude range along with other various waveform attributes.

Interval Attributes
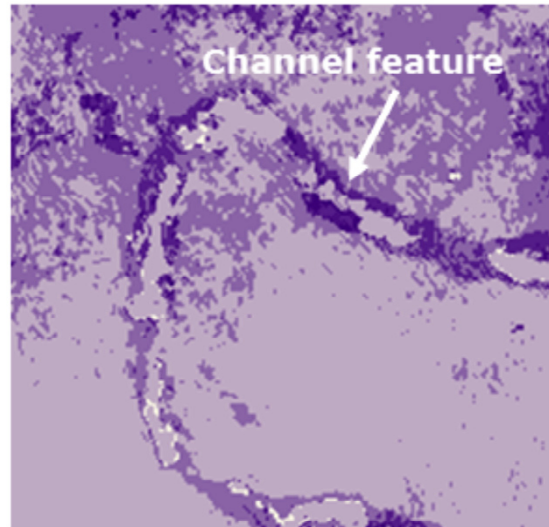
a) Zero crossing interval attribute

b) Absolute amplitude interval attribute

Presenter's notes: Two examples of interval attribute images from the western Canada sedimentary basin. (a) Interval attribute of a Cretaceous channel; the attribute calculates the number of zero crossings over a 35ms interval; (b) Absolute amplitude attribute showing two pinnacle Devonian reefs; attribute determines the peak amplitude over a 60 ms interval.
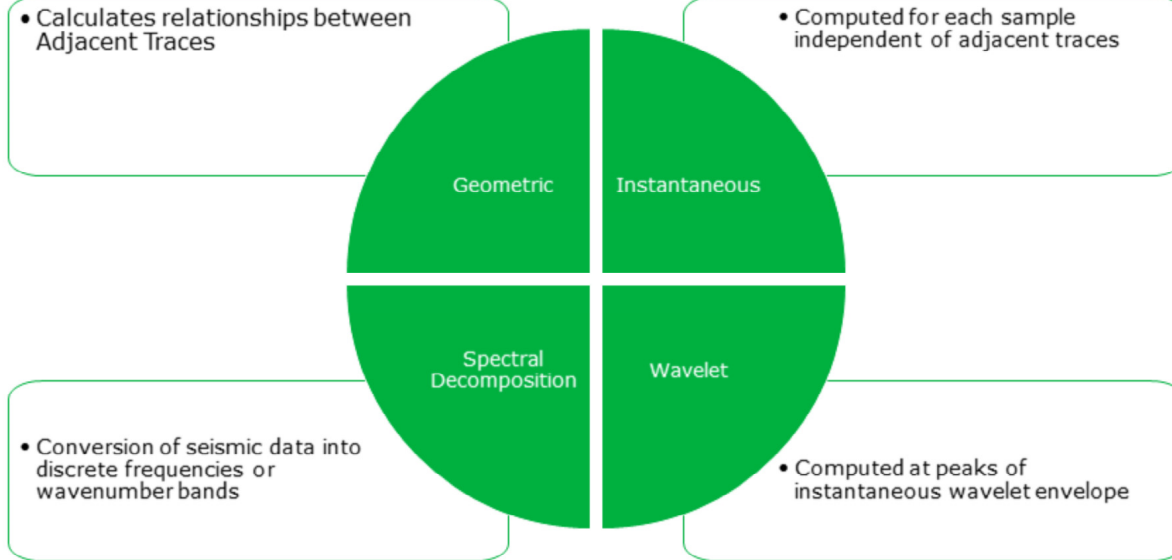
Presenter's notes: **Geometric :**
At each trace geometric attributes are calculated by scanning adjacent traces and computing various characteristics (dip, continuity, etc.).
Initially thought to help with stratigraphic interpretation, but they have been found to be beneficial in recognizing depositional features and related lithology.

Instantaneous:
Calculated for each sample along a trace.
The basis for the computation of most instantaneous attributes is the complex trace model of the seismic wavelet consisting of the real part and imaginary part.

Wavelet:
Similar to instantaneous but they are computed at the peaks of the instantaneous wavelet envelope.
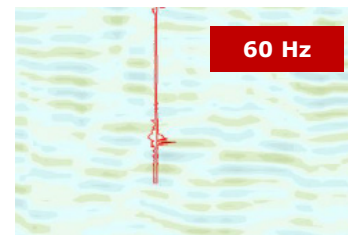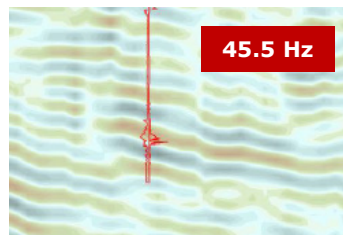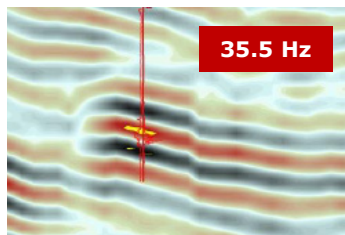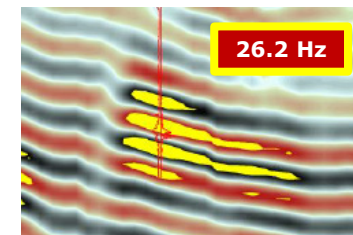
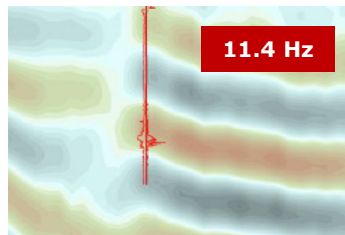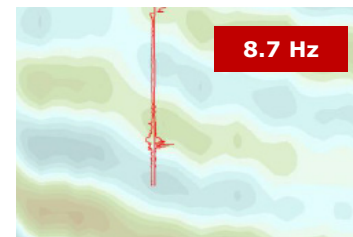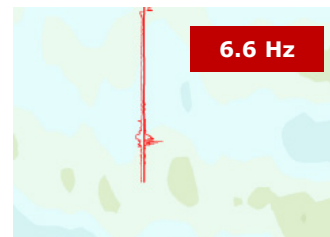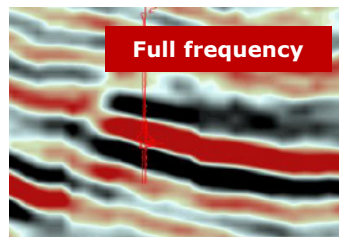**Spectral Decomp:**
Separate volume for each sub-band
Layer thickness determinations
Stratigraphic variations
DHI characteristics (e.g. attenuation)

# Spectral Decomposition –Trace sub-bands by Octaves
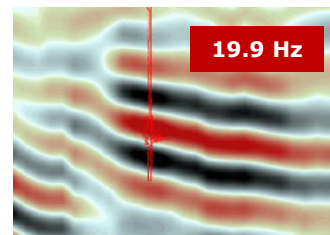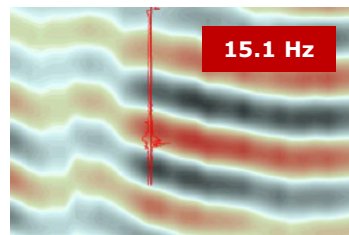
Geological Uses of Seismic Attributes

- **Depositional Environment**
- **Bedding indicators**
- **Unconformities**
- **Continuity/discontinuity**
- **Lithology**
- **Fault detection**
- **Fractures**
- **Hydrocarbon indicators**
- **Absorption**
- **Porosity**

|	Attribute	Local – Both* – Regional	Depositional Environment	Bedding Indicators	Unconformities	Continuity / Discontinuity	Lithology	Fault Detection	Fractures	Hydrocarbon Indicators	Absorption	Porosity
	Acceleration of Phase	Loc				X				X		
I	Band Width	Loc								X		
N	Dominant Frequency	Loc	X	X			X		X	X		
S	Envelope Modulated Phase	Loc			X							
T	Envelope Second Derivative	Loc	X				X					
A	Envelope Time Derivative	Loc			X					X		
N	Imaginary Part		Used to Calculate other Attributes									
T	Instantaneous Frequency	Loc	X	X			X		X	X		
A	Instantaneous Frequency, Envelope Weighted	Loc	X	X			X		X	X		
N	Instantaneous Phase	Loc	X			X						
E	Instantaneous Q	Loc								X	X	X
O	Normalized amplitude	Loc			X							
U	Real Part		Used to Calculate other Attributes									
S	Relative Acoustic Impedance	Loc		X	X	X						X
	Thin Bed Indicator	Loc	X	X		X						
	Trace Envelope (Reflection Strength)	Loc	X		X		X	X		X		X

Reconnaissance Techniques

- **Time Slices:**
  - **horizontal stratigraphy**

- **Horizon Slices:**
  - **Non-parallel reflections**
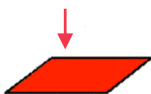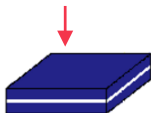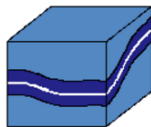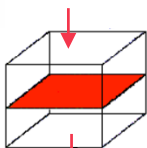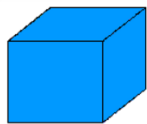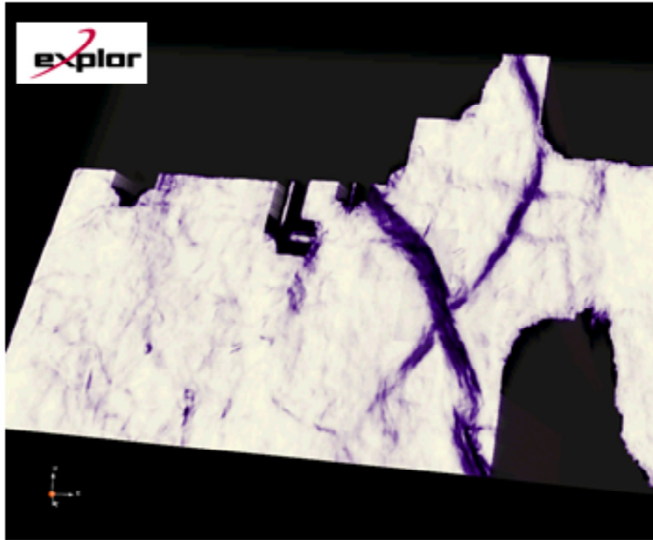
Reconnaissance Techniques
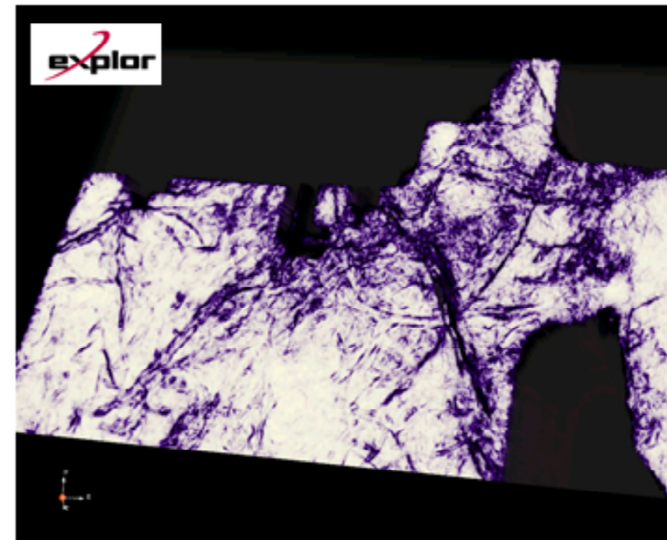
- **Parallel Stratigraphy – DJ Basin, CO**
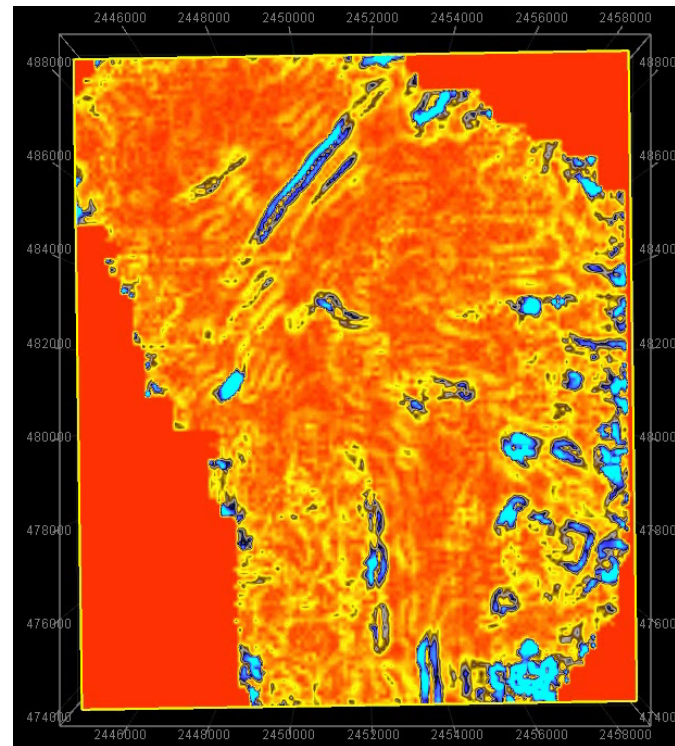
Time slices

Reconnaissance Techniques

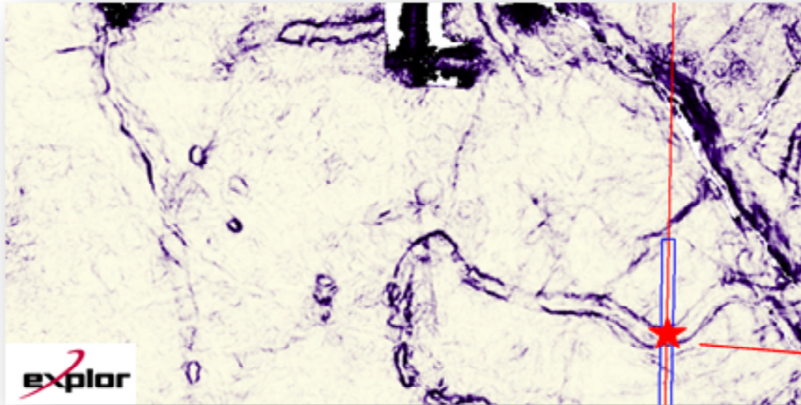Non Parallel Stratigraphy – Western Canadian Sedimentary Basin

Time slices
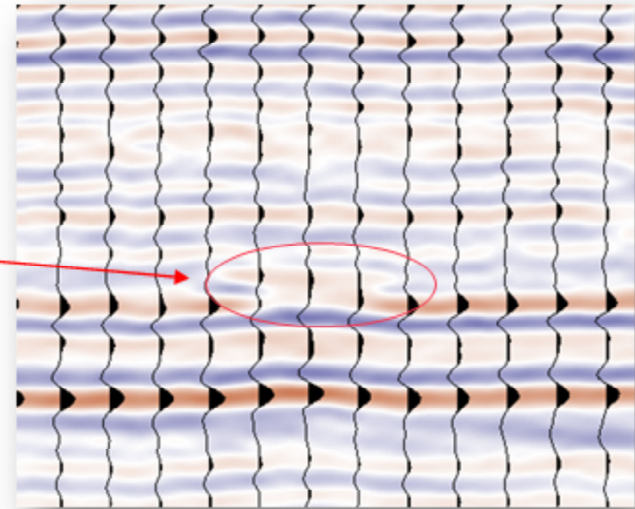

Horizon slices

Presenter's notes: Two examples of interval attribute images from the western Alberta Canada sedimentary basin.

Reconnaissance Techniques

Horizon slice view of a channel

Cross-section view of a channel

Presenter's notes: When slices reveal the presence of features of interest in map view, it is essential to examine the feature in cross section to confirm that what has been observed is stratigraphic rather than structural in origin, and that the feature is not a seismic data acquisition or processing artefact

3d Perspective Rendering

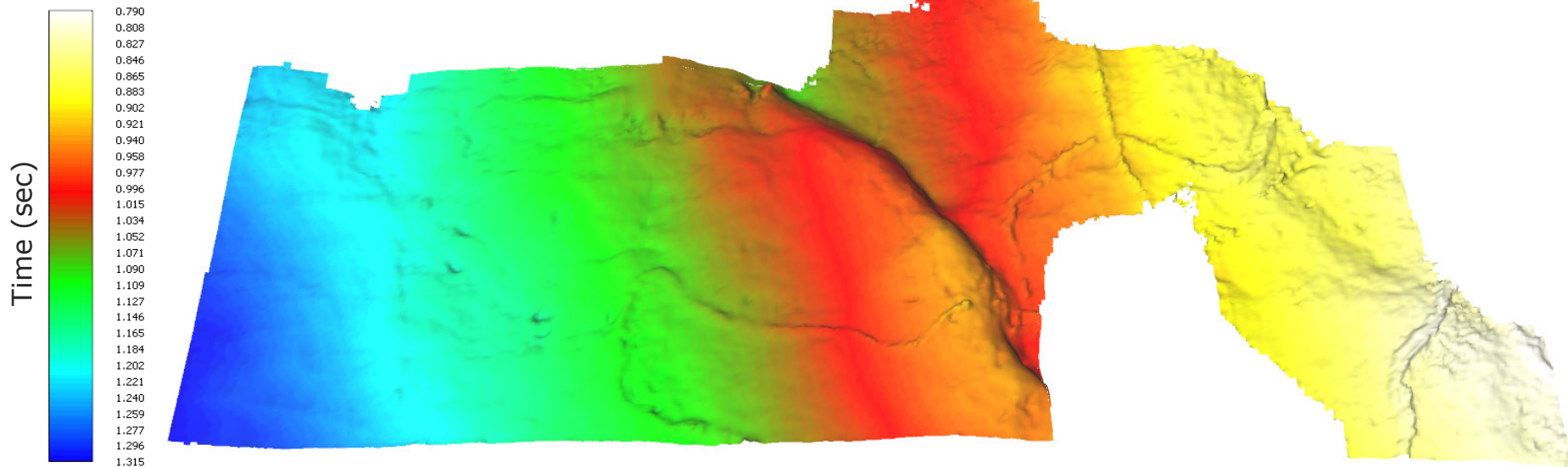- **View an interpreted horizon in 3d perspective to bring out features.**
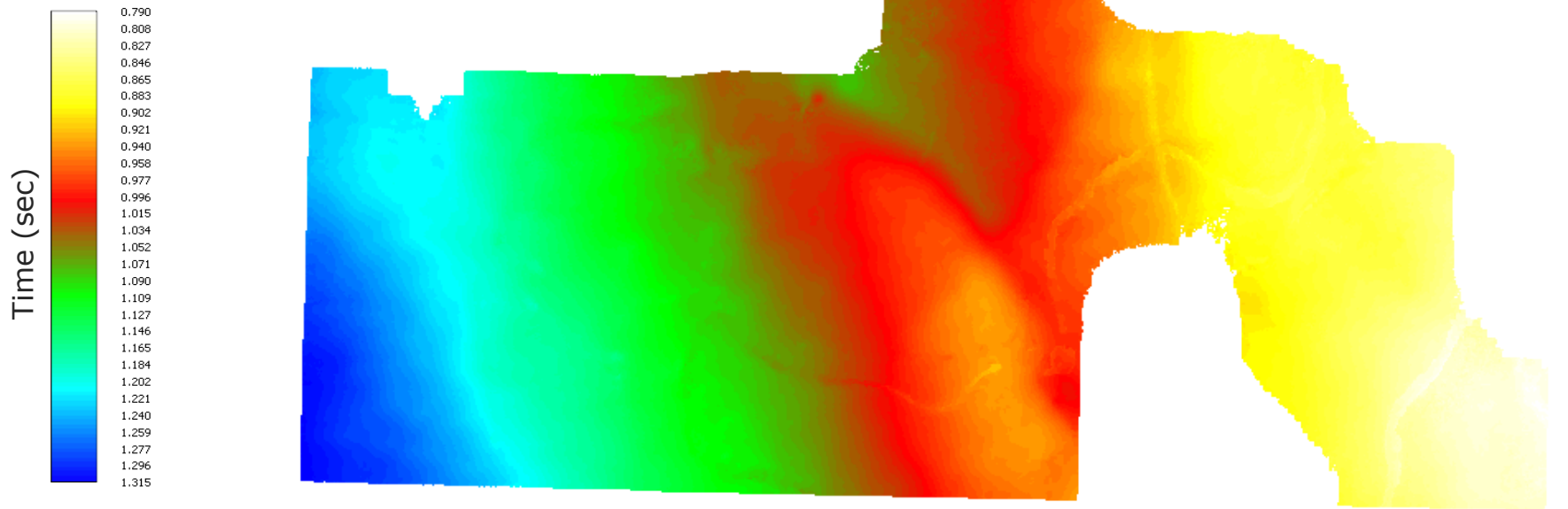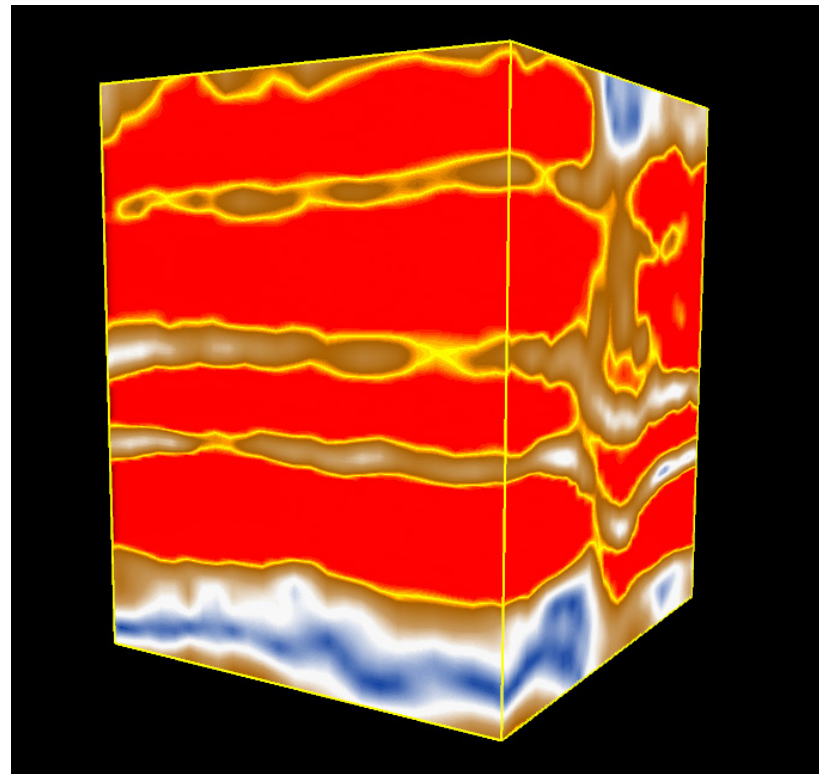
3d Perspective Rendering

- **View an interpreted horizon in 3d perspective to bring out features.**

Opacity Rendering

- **Make unwanted features transparent…peer through a volume and see specific elements with a certain amplitude range.**

Trace Envelope
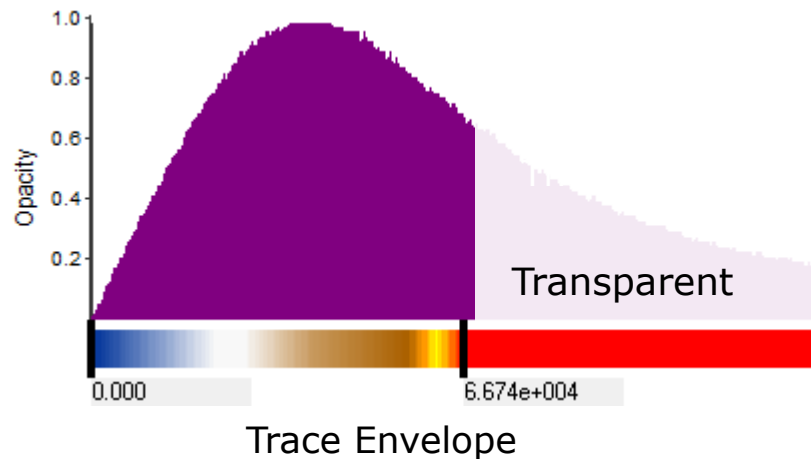
Karst induced feature: Boonesville Area, North Central Texas

Opacity Rendering

- **Make unwanted features transparent...peer through a volume and see specific elements with a certain amplitude range.**
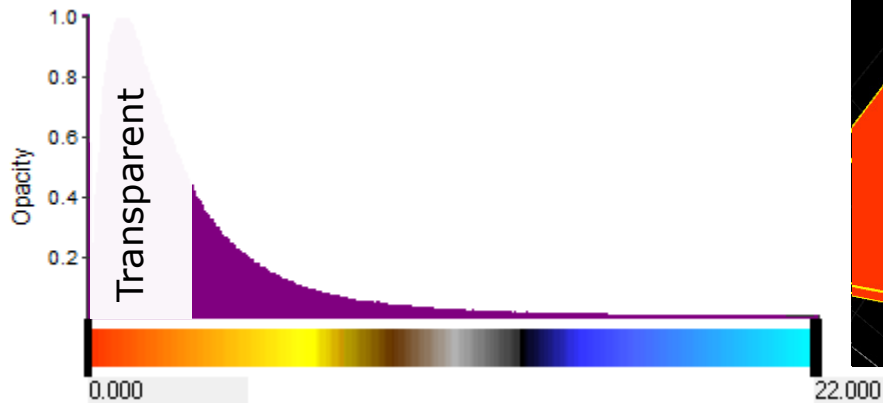
32 Sub Band Instantaneous Dip
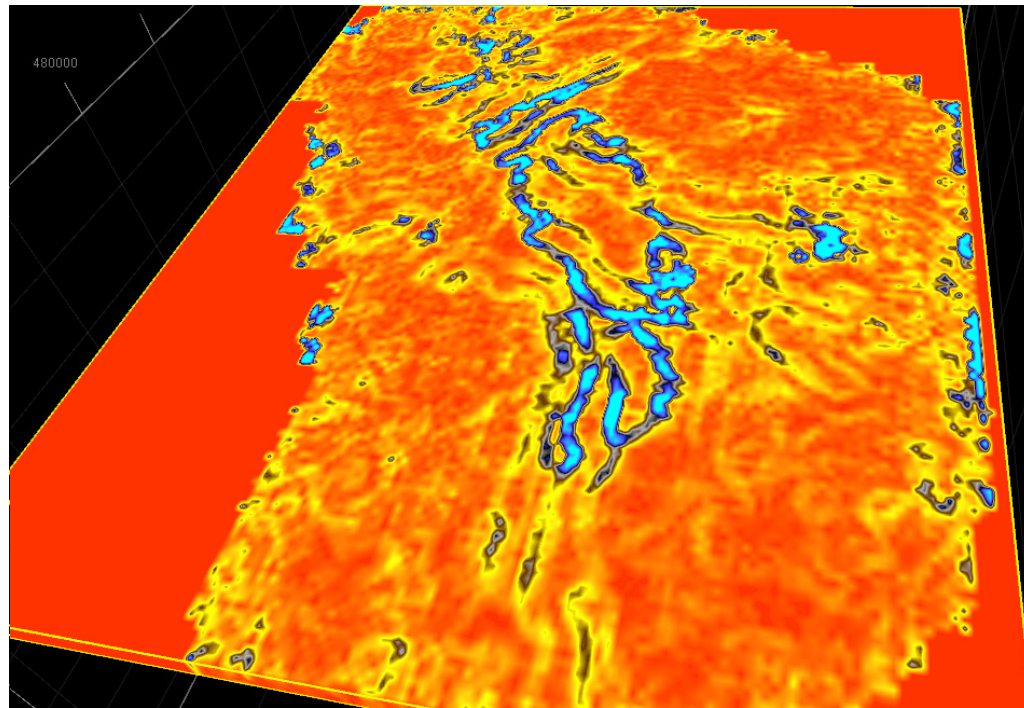
Lower Cretaceous D Sand Channels: DJ Basin, CO

Voxbody Interpretation

- **Picking of connected voxels with user selected attribute amplitude range**

  - **Geo-body picking**

https://en.wikipedia.org/wiki/Voxel
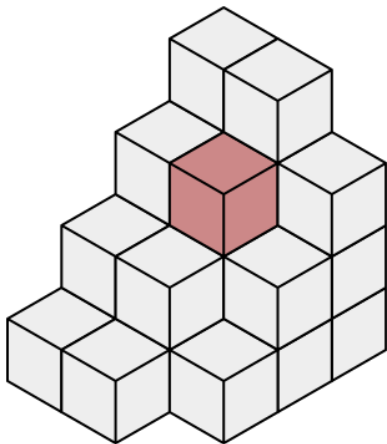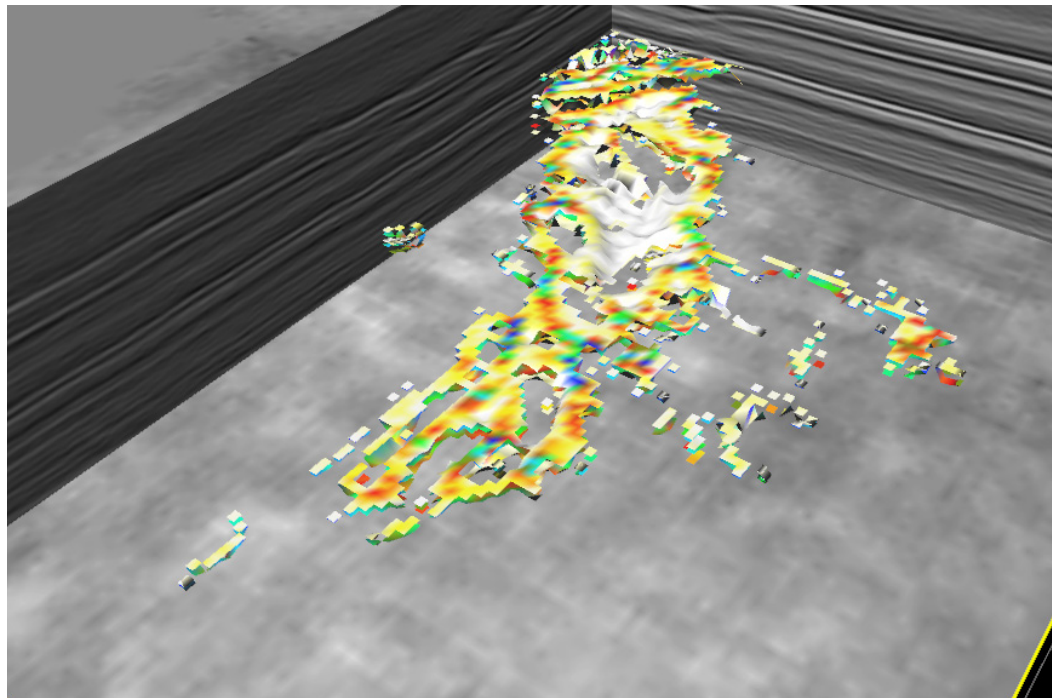
Lower Cretaceous D Sand Channels, DJ Basin, CO

Colorbars

- **Color bar selection and optimization**

Lower Cretaceous D Sand Channels, DJ Basin, CO

Color bars

- **Color bar animation**
  - **Subtle features "appear" with rotating color bar**

Hidden Feature: Western Canadian Sedimentary Basin

Pseudo Cube

- Set of horizons sharing same coordinates

- Horizons come from different SD cubes

- Horizons shifted in respect to each other
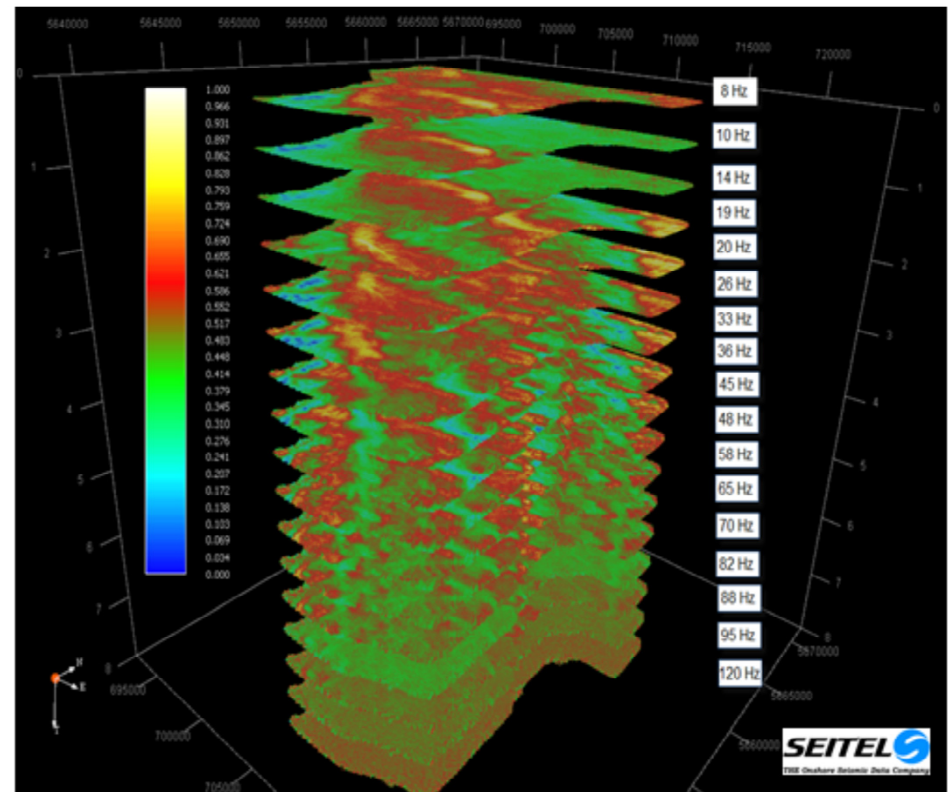
- Can be animated

Presenter's notes: The concept of the Pseudo Horizon Cube stems from the idea that it is easier for the human eye to recognize patterns through dyn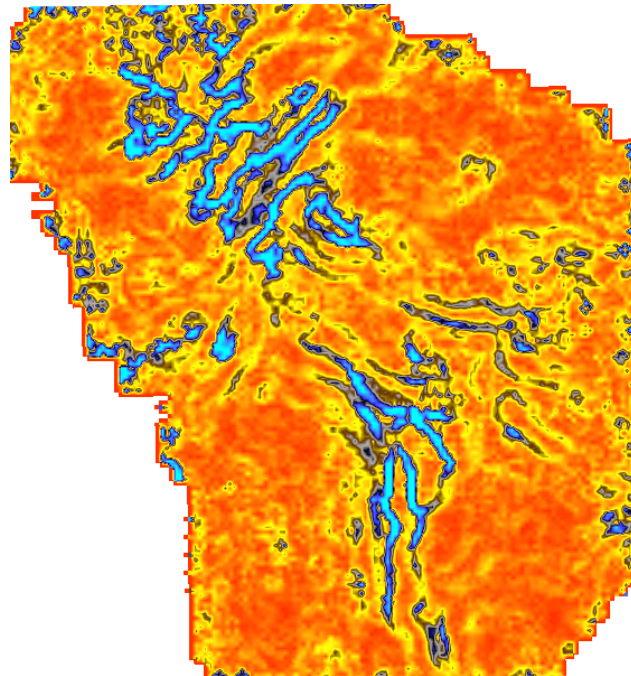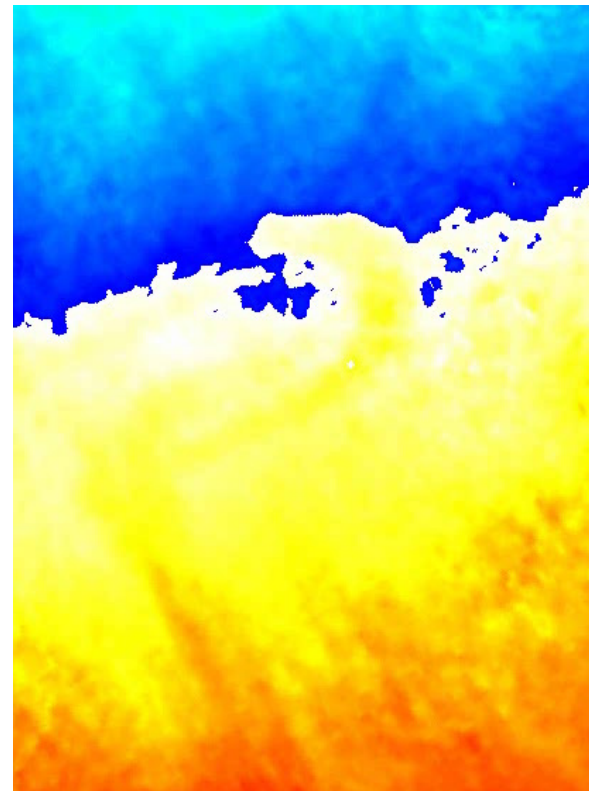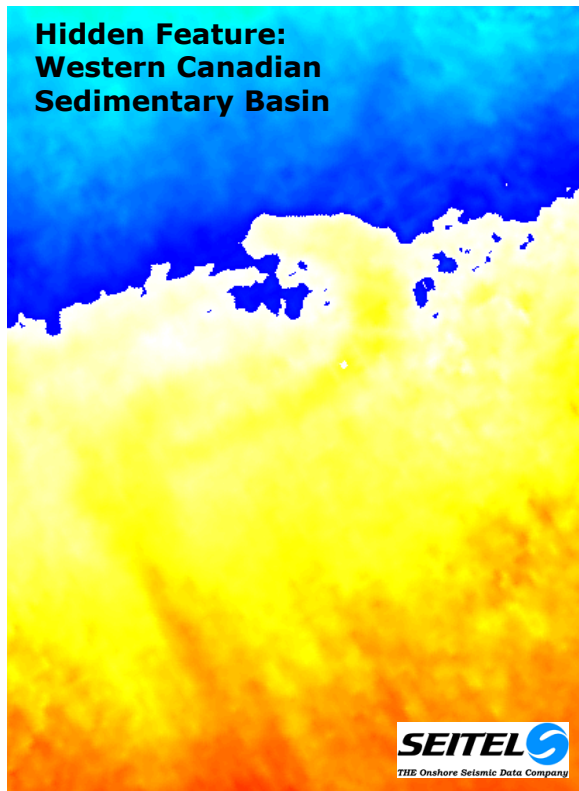amically changing, animated set of images than from the static one. One way to implement this concept in Kingdom is to create a set of horizons (that could either be autopicked on 3D seismic data, or simply created from "time" slices) that share the same (x, y, t) coordinates, but come from different Spectral Decomposition cubes. We also need to shift these horizons with respect to each other by changing the t coordinate by utilizing Kingdom calculator, so that we obtain the following set of Spectral Decomposition slices

Pseudo Cube

- Set of horizons sharing same coordinates

- Horizons come from different SD cubes

- Horizons shifted in respect to each other
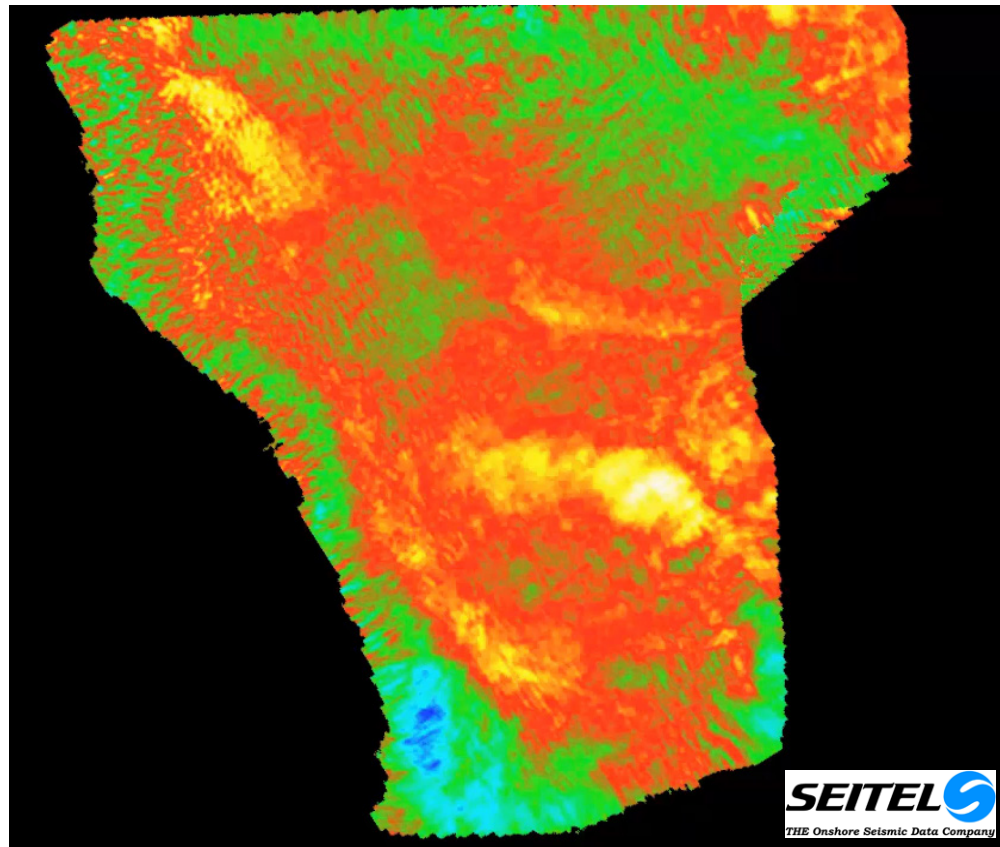
- Can be animated

RGB Blending

- Blending of three spectral decomposition bands:
  - Red
  - Green
  - Blue

- Enhances ability to recognize channels

Summary

- Understanding depositional systems using 3D seismic data analysis

- Identification and visualization of discrete depositional elements

- Analytical techniques:

  - Horizon and interval attributes

  - Seismic attributes

  - Time and horizon slicing

  - Perspective and opacity rendering

  - Voxbody interpretation

  - Color bar selection and animation

  - Pseudo cube and RGB blending

Acknowledgements and references

- Seismic data from

explor

SEITEL
THE Onshore Seismic Data Company

- Posamentier, H.W. 2005. *Application of 3D seismic visualization techniques for seismic stratigraphy, seismic geomorphology and depositional systems analysis: examples from fluvial to deep-marine depositional environments.* In book: Petroleum Geology: North-West Europe and Global Perspectives – Proceedings of the 6th Petroleum Geology Conference, pp.1565-1576

- Posamentier, H.W. 2000. *Seismic stratigraphy into the next millennium; a focus on 3D seismic data.* American Association of Petroleum Geologists Annual Conference, New Orleans, LA, April 16–19, 2000, A118.

Presenter's notes: The study of depositional systems in time and space has benefited greatly from analyses of 3D seismic data. Through a combination of plan views and section views, discrete depositional elements can be identified and visualized, and ultimately interpreted with regard to paleogeography, temporal evolution and lithology. This approach constitutes an integration of seismic geomorphology (i.e. plan views) and seismic stratigraphy (i.e. section views). Interpretation of 3D seismic volumes can involve a variety of analytical techniques ranging from mapping, visualizing and characterizing attributes of seismic horizons, to performing amplitude extractions from seismic slices, to characterizing seismic attributes of seismic intervals. Knowledge of map view expression of a range of depositional elements as well as a sound understanding of stratigraphic architecture is essential for this approach. From an exploration perspective, the identification of depositional elements facilitates lithology prediction because most depositional elements have a somewhat predictable distribution of rock types.