SEISMIC DATA ATTRIBUTES

Manual

Seismic Data Attributes	2
Barents Sea Example	3
Load data	4
Attributes	
1. Fluid Factor	5
2. Lithology based fluid indicator *instantaneous frequency	6
3. Amplitude envelop	7
4. Lithology based fluid indicator *amplitude weighted frequencies	8
5. Lithology based fluid indicator *integrated	9
6. Poisson's ratio (pseudo-Poisson's)	10
7. Pay Zone	11
8. IGT	12
9. Density	15
Required data /Literature /Software	16

SEISMIC DATA ATTRIBUTES

Vita Kalashnikova, QI Geophysicist PSS-Geo AS

Most modern software packages include attribute modules, but very few of them in are actually used. Here is an example of the complexity that geologists face when using seismic attributes: *Hilbert transform of the imaginary part of the Complex trace* - this is an attribute which will never be in use.
Most on the G&G departments limit their research to AVO or to some simple “screening attributes scan” analysis. Modern software attributes modules can be applied directly to the seismic section, while more sophisticated lithology and fluid based attributes are typically handed down to other expensive software/module and required external geophysicist expertise, even though they are actually of simple computation.

This Manual is simplified explanation of 12 Seismic Data Attributes package. It includes physical explanation of an attribute and its interpretation, recommendation of the color code, and suggested geological interpretation of seismic section base on this attributes.

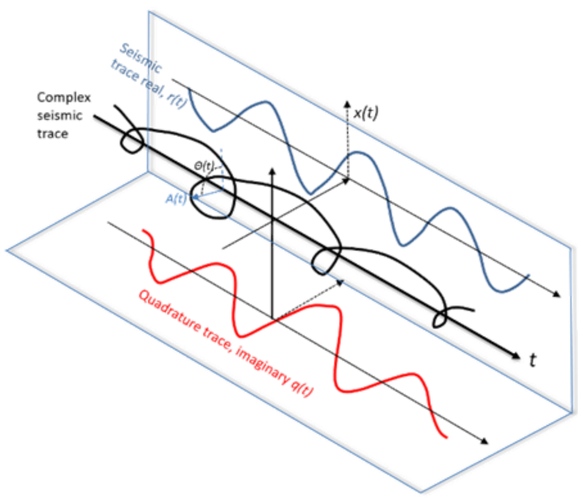
Note! The attributes sections are not scaled sections. The color scale should be adjusted to the working time window (except for the IGT section). Conclusion about possible hydrocarbons in reservoirs can only be done when all hydrocarbons related attributes indicate hydrocarbons at the same event.

Seismic Data Attributes
The traditional interpretation of seismic data is based on the temporal and spatial variations of fundamental seismic data properties: reflection amplitudes, reflection phase and wavelet frequency. Quantitative parameters of seismic data can be very precious to get more information and reduce the ambiguity of the results of traditional seismic interpretation.
Analysis of seismic data attributes gives a structural and stratigraphic understanding of the geologic conditions. Different approaches extract and display various amplitudes, phases and frequencies in convenient, understandable format.
The basis of attributes computation is modified Aki-Richards equation (Intercept/ Gradient/ Curvature) [1], Geostack method described by Fatti et al. (1994) [2], and decomposition of complex seismic trace followed by Hilbert transform, see Pic. 1.

Package of attributes includes:

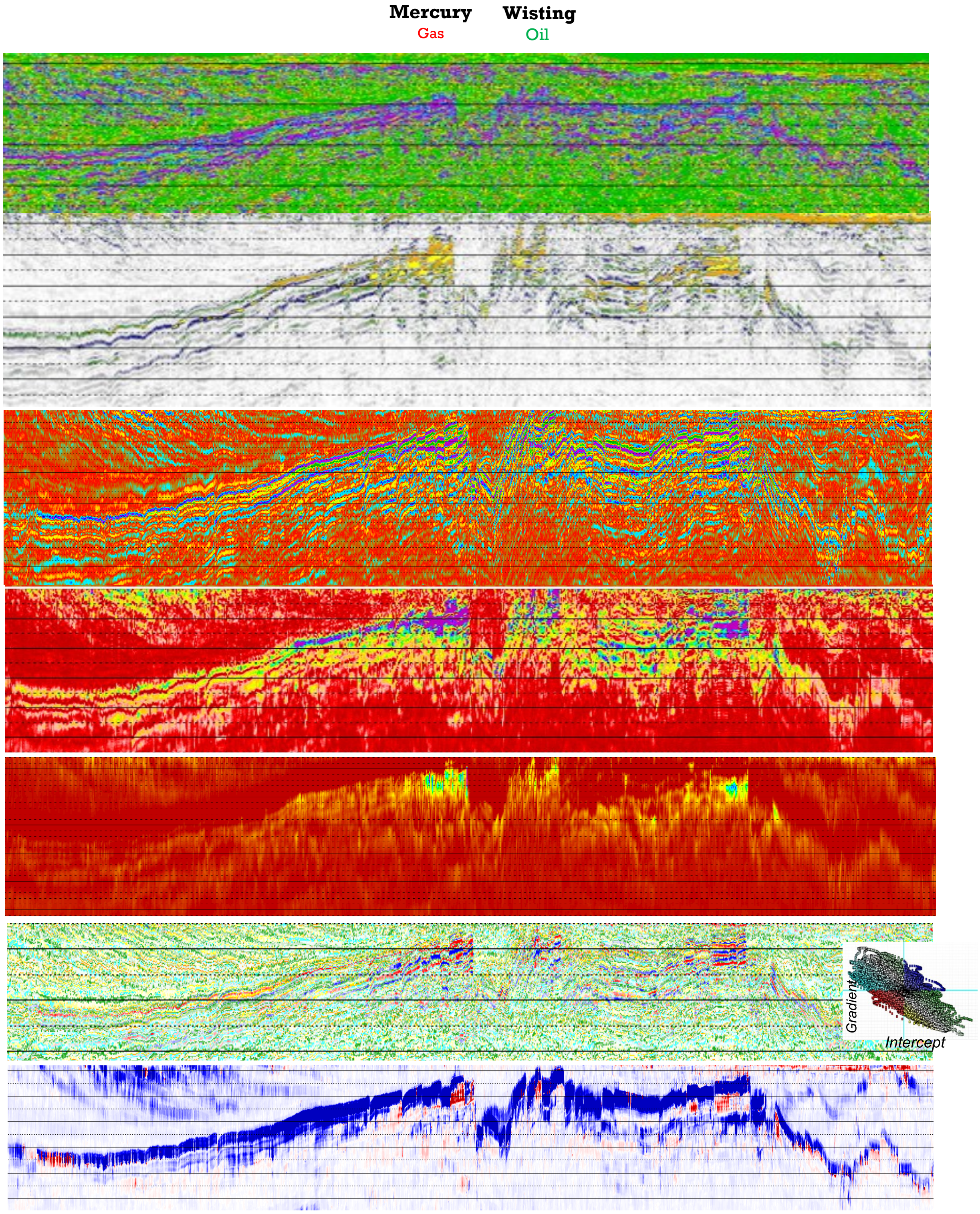
In SEGY format
1. Envelope
2. Fluid Factor
3. Lithology based fluid indicator
   *instantaneous frequencies
4. Lithology based fluid indicator
   *amplitude weighted frequencies
5. Lithology based fluid indicator
   *integrated
6. Poisson’ ration
   Pay Zones
7. *polarization product
8. *angel of crossover
9. Intercept
10. Gradient
11. IGT
12. Relative Density

In pdf format
Description of interpretation (this Manual)
In txt format
Color code



Picture 1. Complex seismic trace

BARENTS SEA EXAMPLE



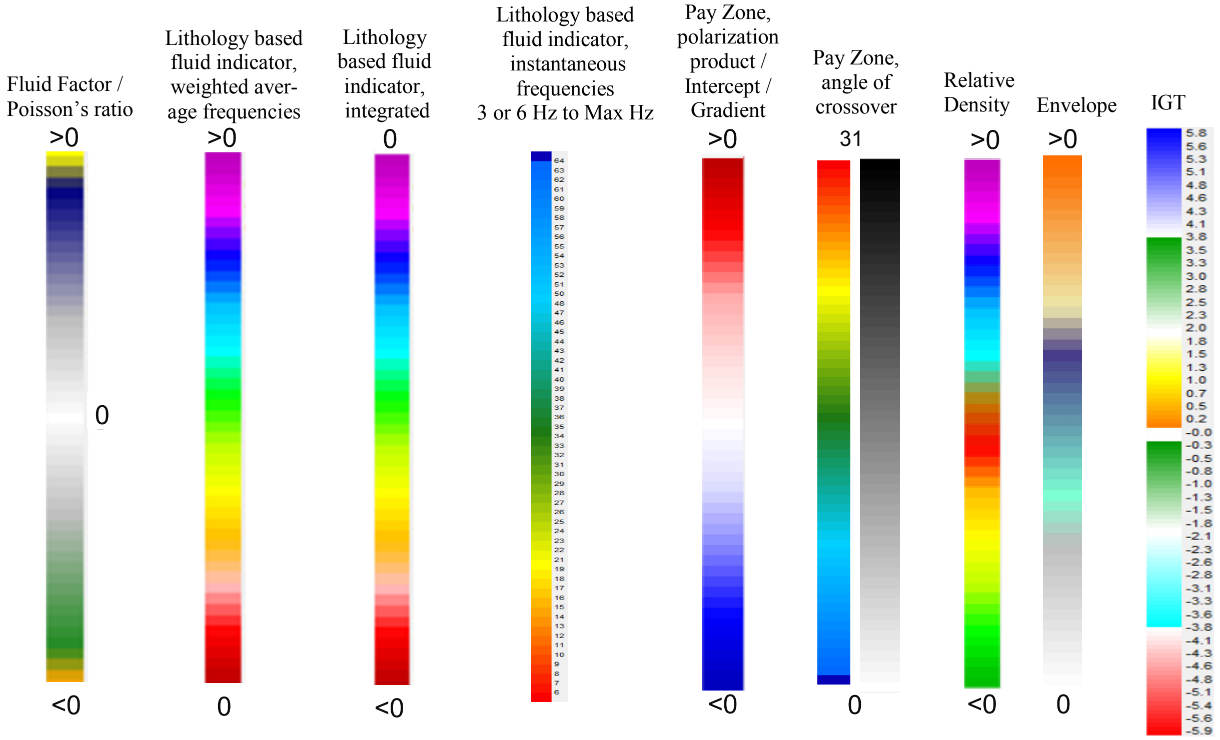
Picture 2. Wisting Discovery. From top to bottom: Rp section, Fluid Factor, Density, Two Fluid Factor related attributes, IGT section and Polarization Product

MULTICLIENT GEOPHYSICAL

Seismic data courtesy of MultiClient Geophysical ASA

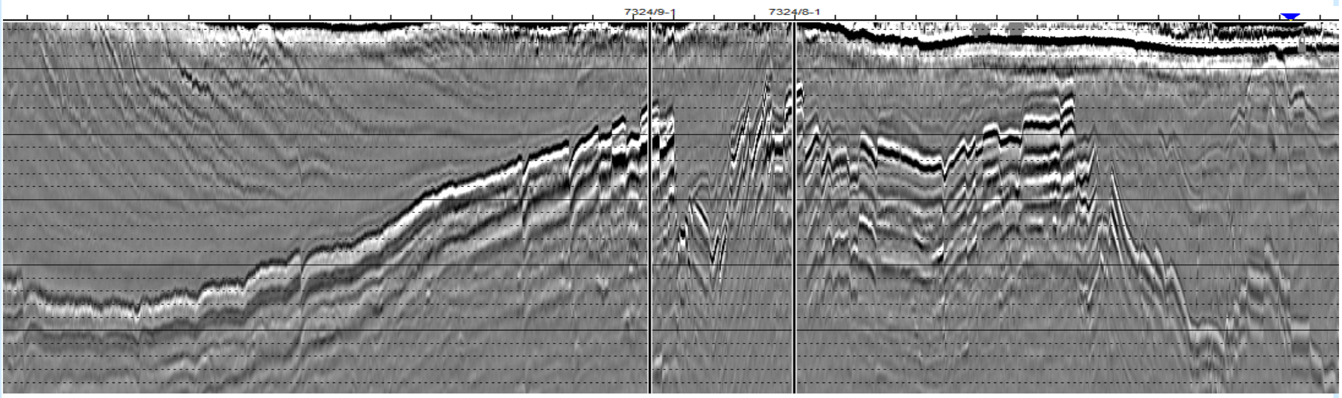
LOAD DATA

1. Load all attributes including Full Stack seismic volume and color code to your software.
2. Choose appropriate color code for each attribute, as it shows below (recommended color codes).
3. Scale color code for working window.



Seismic section. Full Stack.
In this Manual the Seismic Data Attributes will be calculated for the seismic section shown below.

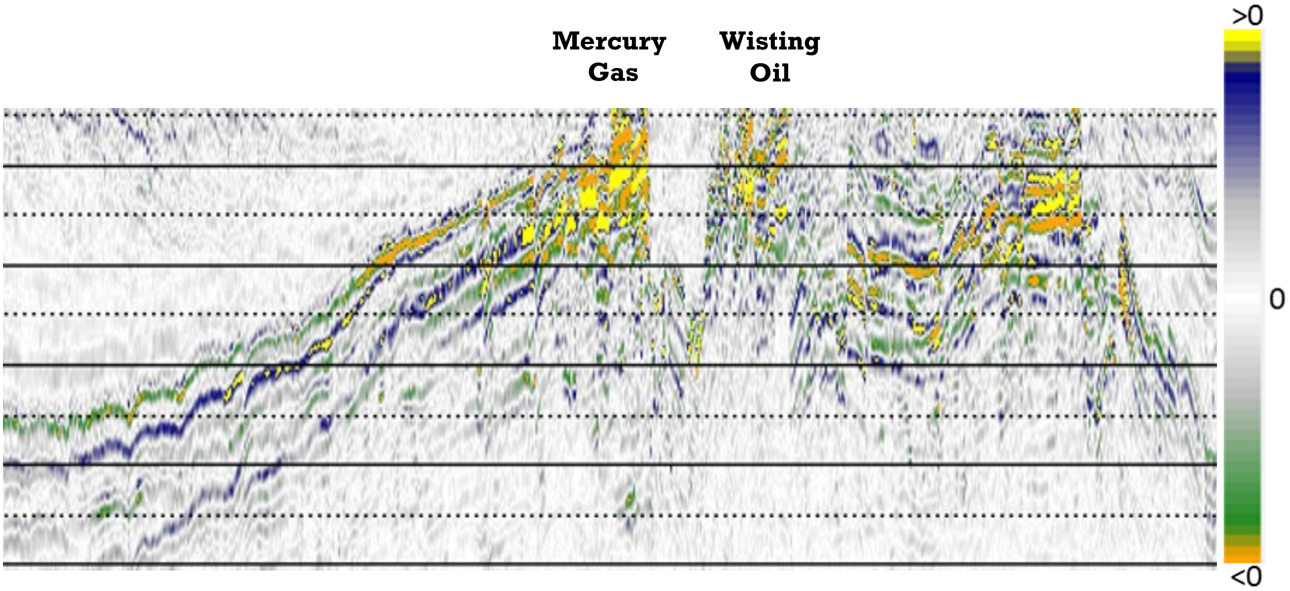
Mercury Gas **Wisting Oil**



ATTRIBUTES

1. Fluid Factor

- *(FFr)* - *FFr=Rp(t)-g(t)·Rs(t), g(t)=M·(Vs/Vp),* where M is a slope of liner approximation on *Vp* vs *Vs* plot. In the examples shown here, to calculate *g(t)* Castagna sandstone mudrock line* is taken for simplification.
The strongest negative events in sandstone layers can be considered as hydrocarbon saturated rocks.
When *Rp(t)-g(t)·Rs(t)=0*, it corresponds to brine saturated rocks, with *Rp(t)-g(t)·Rs(t)<0*, it can be considered as hydrocarbon saturated rocks. Finally, when *Rp(t)-g(t)·Rs(t)>0* this is considered as a hard event.
g(t) is the most important coefficient which can be calculated using available well logs data. When properly calculating *g(t)* coefficient along the well path, its application to the seismic section gives the most accurate lithology based fluid indicator.
Another way to calculate FFr is to estimate g(t) empirically from the traces (Gidlow et al., 1992) - the best overall fit to mudrock line trend [3].
Brine saturated siliciclastic rocks have low reflector amplitudes, and gas rocks will be brightening up even more, because reflection amplitudes will lie off the mudrock line. Carbonates, igneous rocks, and several other lithologies should be carefully studied on this attribute because they may also show brightened up [4].

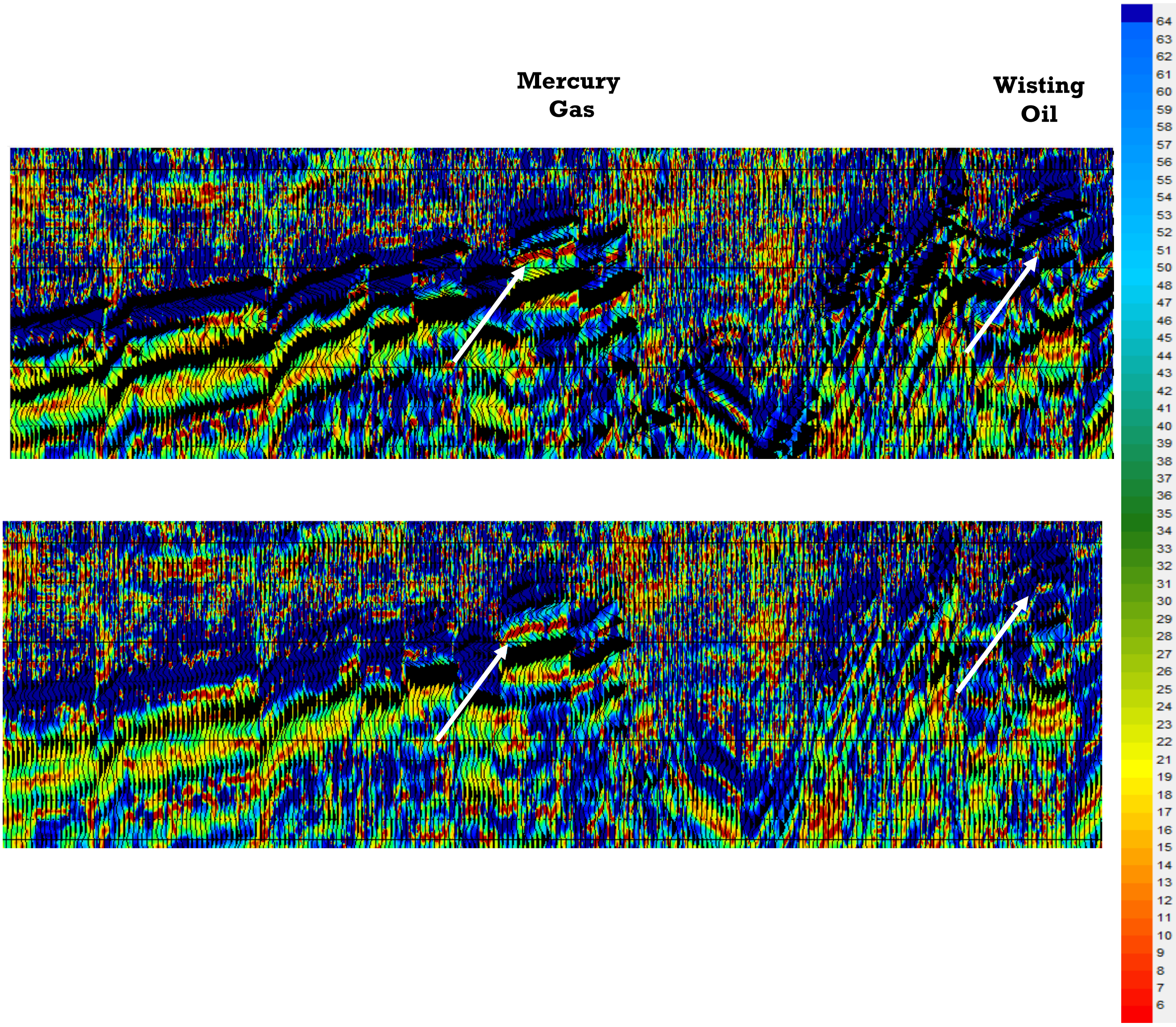


** Mudrock line is an empirical linear relation between seismic P-wave velocity (Vp) and S-wave velocity (Vs). Introduced by Castagna, J. P.; Batzle, M. L.; Eastwood, R. L. (1985). "Relationships between compressional-wave and shear-wave velocities in clastic silicate rocks." Geophysics 50: 571–581.*

2. Lithology based fluid indicator *instantaneous frequency

This attribute shows the lower frequencies often seen below gas sands in bright spots.

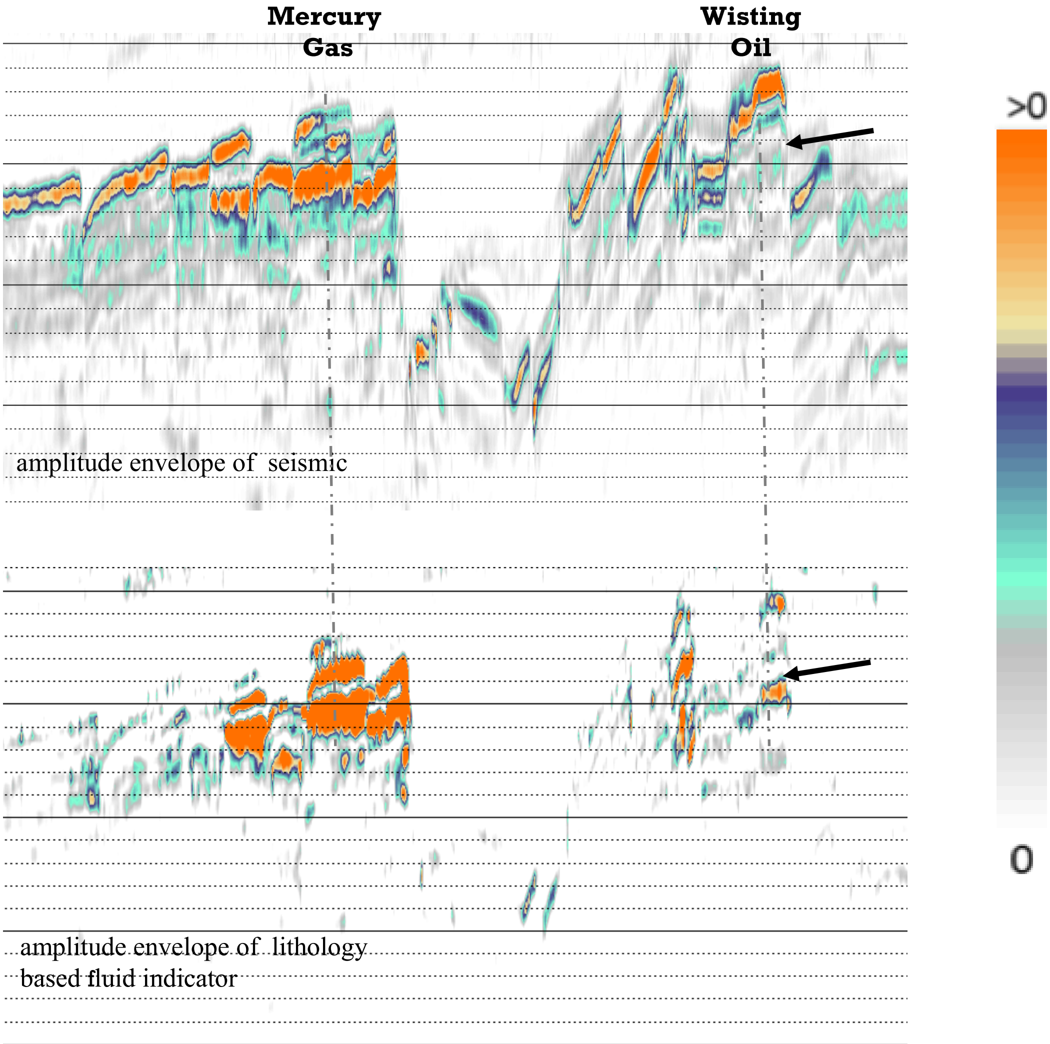
$\omega(t)=d(\theta)/dt$ — instantaneous frequency is the time derivative of the instantaneous phase $\theta(t)$, see Pic. 1. This attribute shows the lower frequencies often seen below gas sands in bright spots: shadows. The low-frequencies shadows effect is described by Taner et al (1979) [5]. It often occurs only on reflectors which lie just below the hydrocarbons layer: gas sand, condensate, and oil. The frequency character of reflections slowly changes according to changes in lithology or thickness. Furthermore the instantaneous frequencies change more rapidly at the edges and wedges. Low-frequency shadows can also indicate fractured fragile rocks.
The instantaneous parameters are associated with the point in time on the seismic pulse; they are not affected by the reflection strength.
Pictures below are seismic section instantaneous frequency and instantaneous frequency section of fluid indicator section.



3. Amplitude envelop

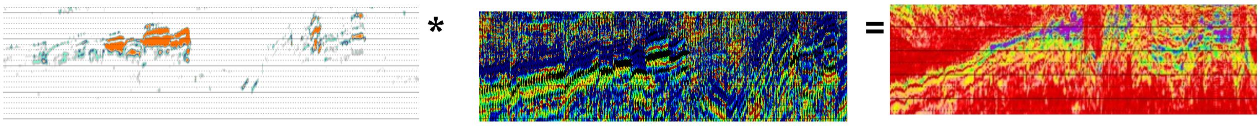
- $A(t)=(q^2(t)+r^2(t))^{1/2}$, $q(t)$ - quadrature trace (Imaginary), $r(t)$ – seismic trace see Pic.1. It is a magnitude of the complex trace, defined by the trace and its Hilbert transform. Also known as instantaneous amplitude. In literature, also can be called as instantaneous energy of signal or reflection strength. It shows lithology changes, bright spots, and thin -bed tuning effects.

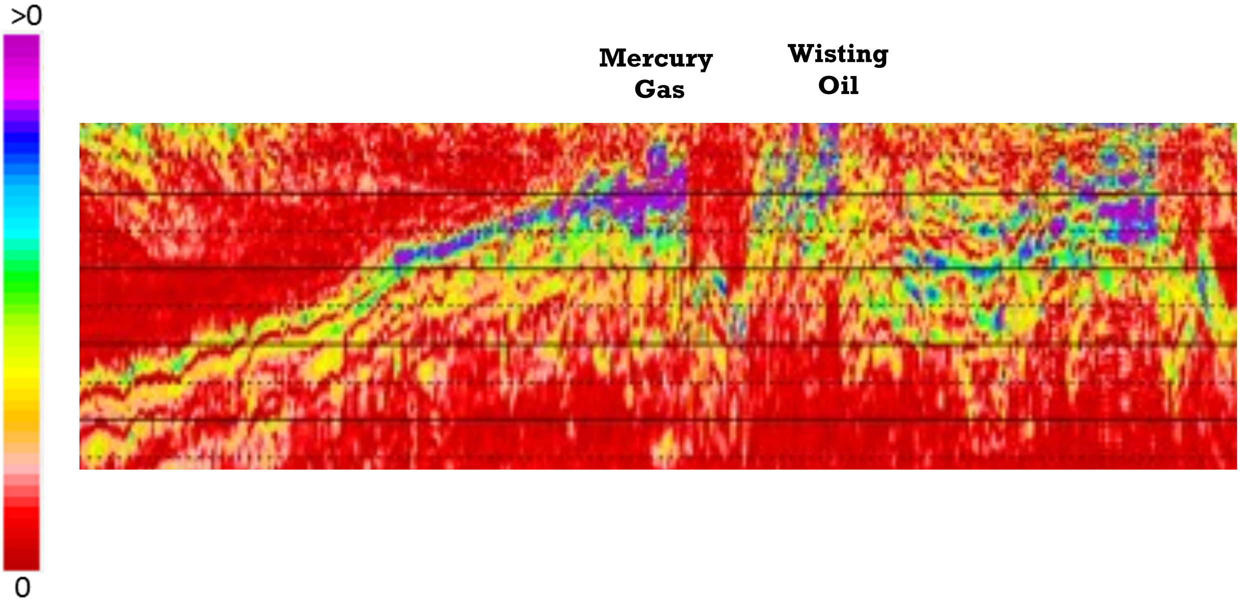
Pictures below are amplitude envelope of seismic section and amplitude envelope of lithology based fluid indicator section. Amplitude envelope of seismic section has brightening over all structures and missed oil reservoir indicator, when amplitude envelope of lithology based fluid indicator section highlights HC areas better.



4. Lithology based fluid indicator
* amplitude weighted frequencies

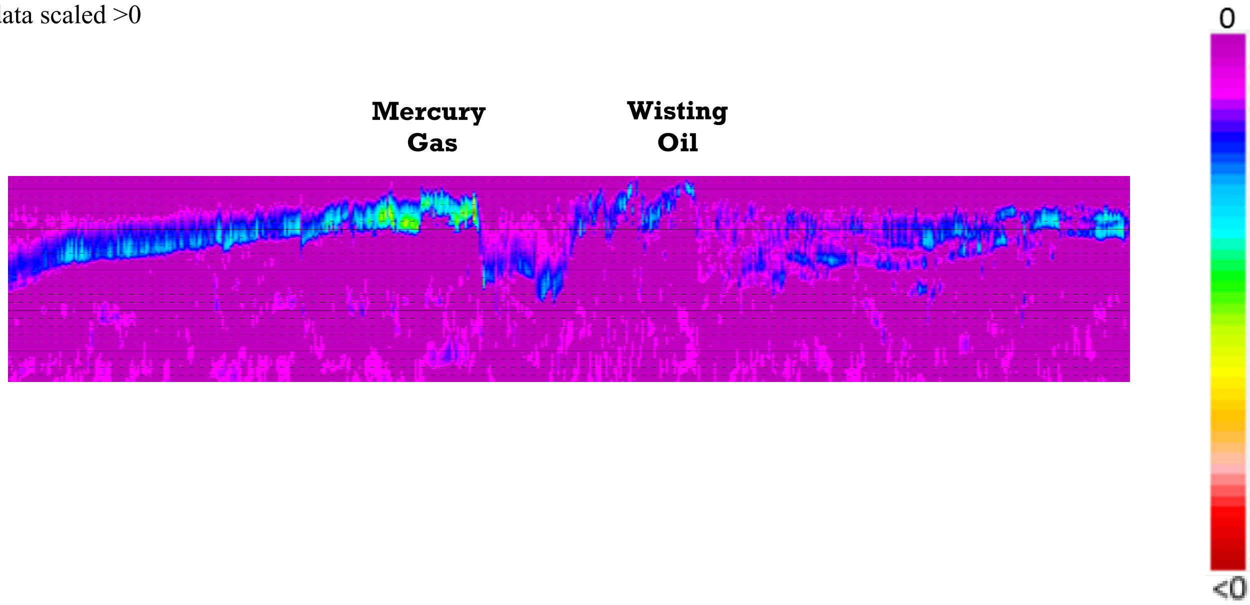
Amplitude weighted frequencies is a product of the amplitude envelope (reflection strength) and the instantaneous frequency Picture below illustrate it.
Amplitude weighted frequencies of Lithology based fluid indicator section highlights lowers impedance layers in more accurate way. Recommended color code is shown on the left side.

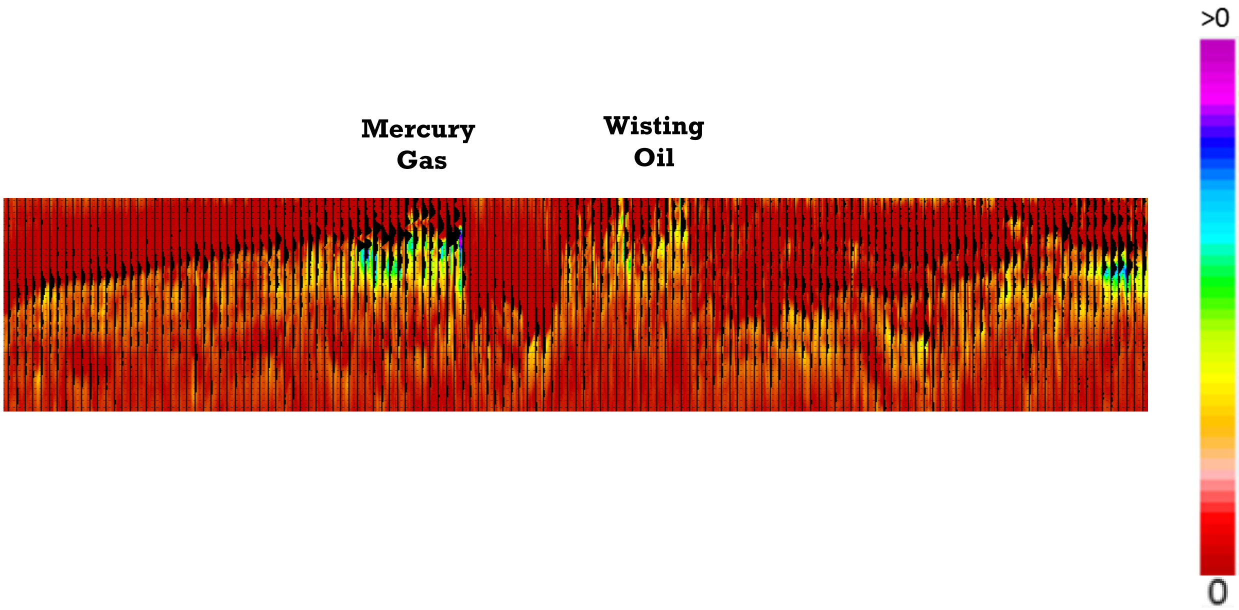




5. Lithology based fluid indicator
**integrated*

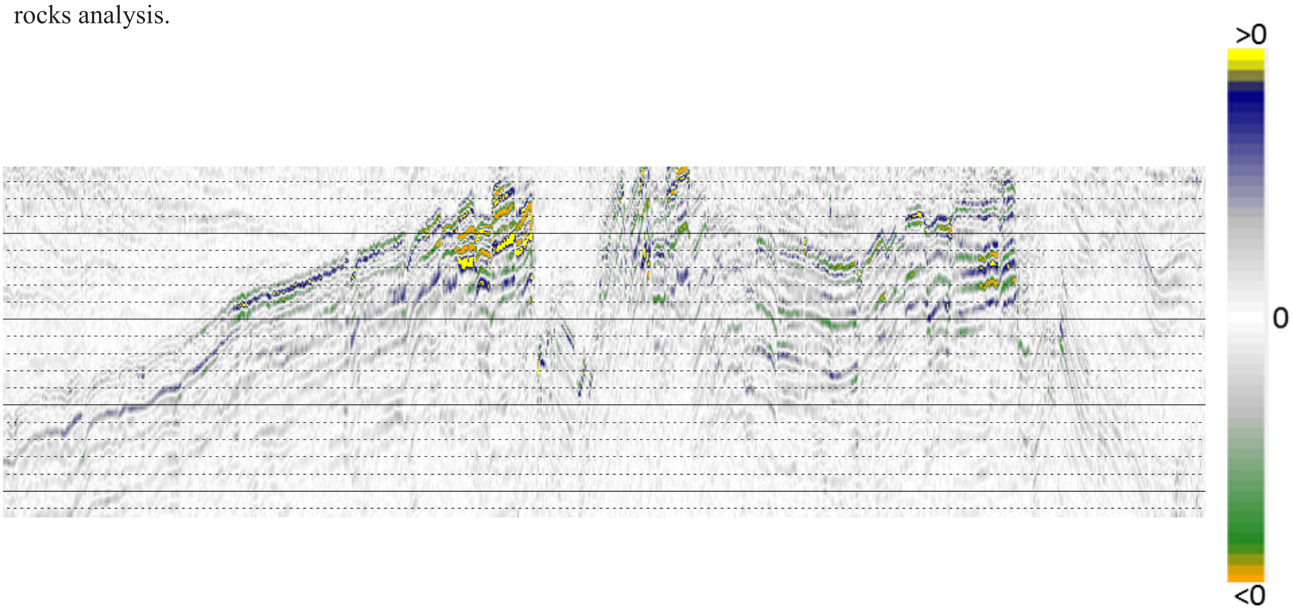
This attribute highlight the strongest and weakest reflections on the calculated section. The *aureoles* can be observed straight above the HC zone when data scaled <0, and *shadows* appeared straight below the HC start zones when data scaled >0





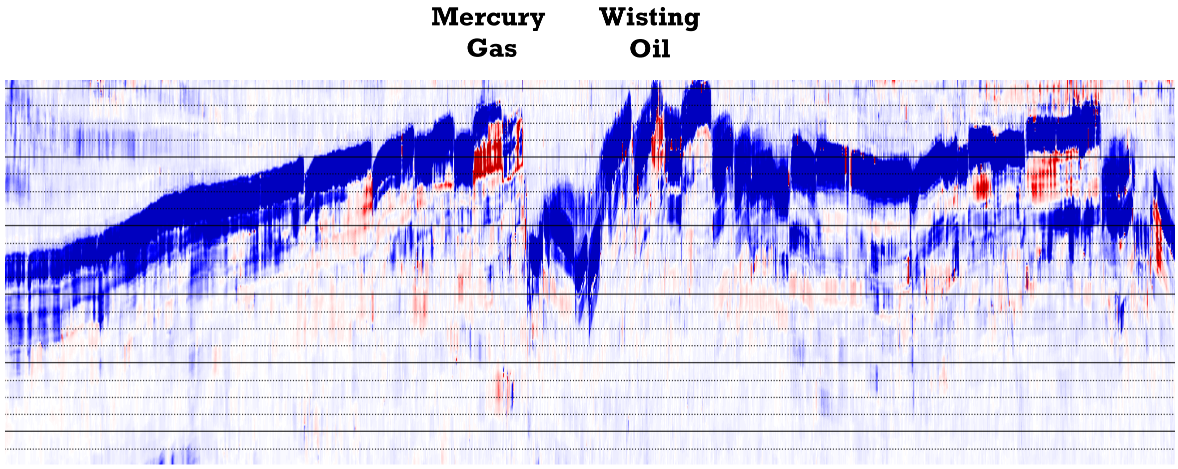
6. Poisson's ratio (pseudo-Poisson's)

– by Smith and Gildow as ratio reflectivity [6]). The pseudo-Poisson's ratio reflectivity of fractional Vp/Vs can be directly calculated from the estimation of P- and S- waves reflectivity and fractional changes in density. This attribute is the calculation of normalised changes in Vp/Vs ratio, which can be directly correlated to lithology and/or pore fluid content changes. Poisson's ratio here is *Rp(t)-Rs(t) (See paragraph 1. Fluid Factor),* can be also used for carbonates rocks analysis.

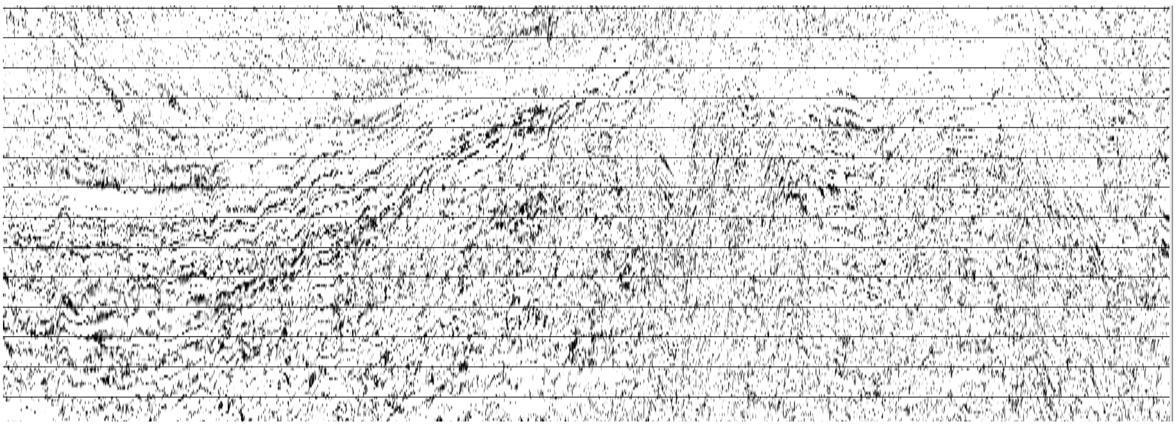


7. Pay Zone

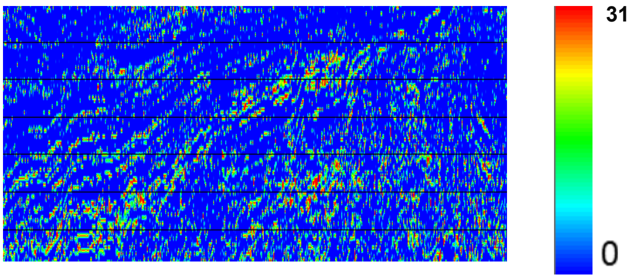
Polarization product — on of the best anomaly indicator.



Pay zone as angle of crossover indicates a polarity reversal effect (highlight mostly AVO classes 2 and 2p). Absolute amplitudes decrease with offset until one reaches the crossover angle, flips polarity, and subsequently increases. Events with this response typically appear weak on the stacked section. Angles greater than 31 degree are outputted as 31 degree. Nevertheless, this polarity reversal effect has been known to indicate rock properties consistent with pay zone.



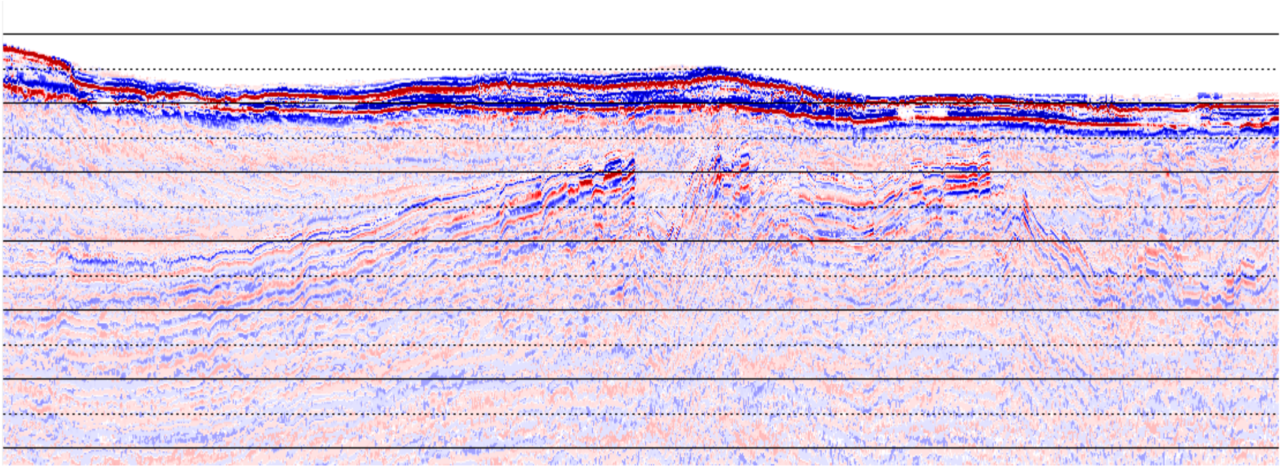
Rainbow color code can show consistent angle of crossover.



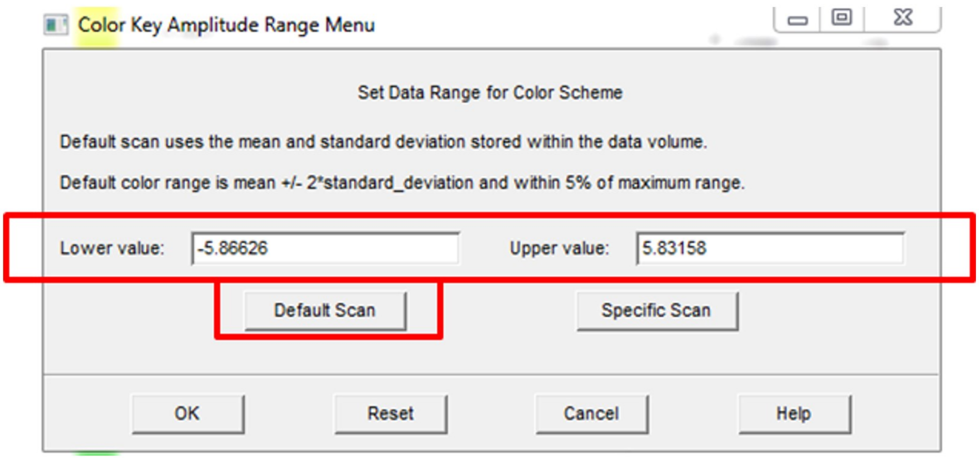
8. IGT Section

– ***Intercept*** – amplitudes at zero-offset.
– ***Gradient*** – the slope of the line on amplitudes vs angles of incident plot.
– ***IGT*** – Section of AVO classes quadrants, where color of the class changes gradually for each quadrant, thus it shows seismic section colored by AVO classes. Section requires color code.

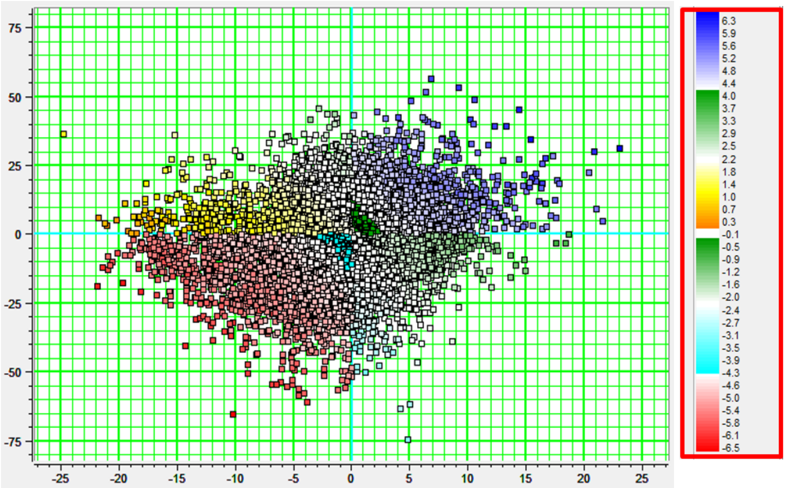
1. Open IGT SEGY Section in your software



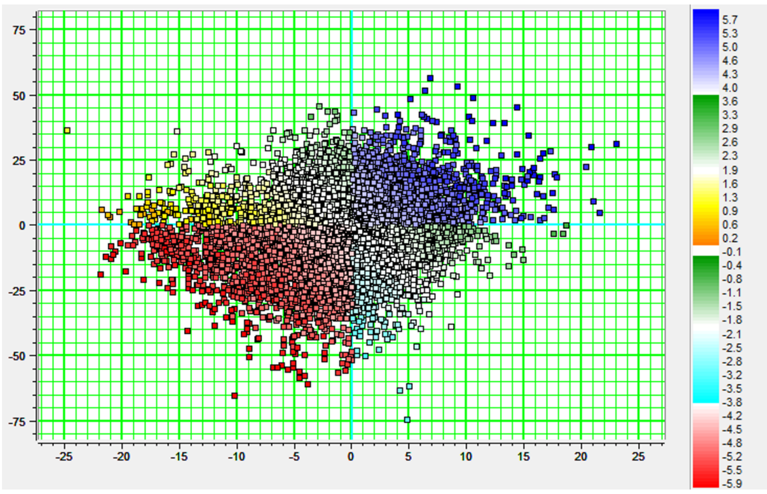
2. Scale your data by *Default*

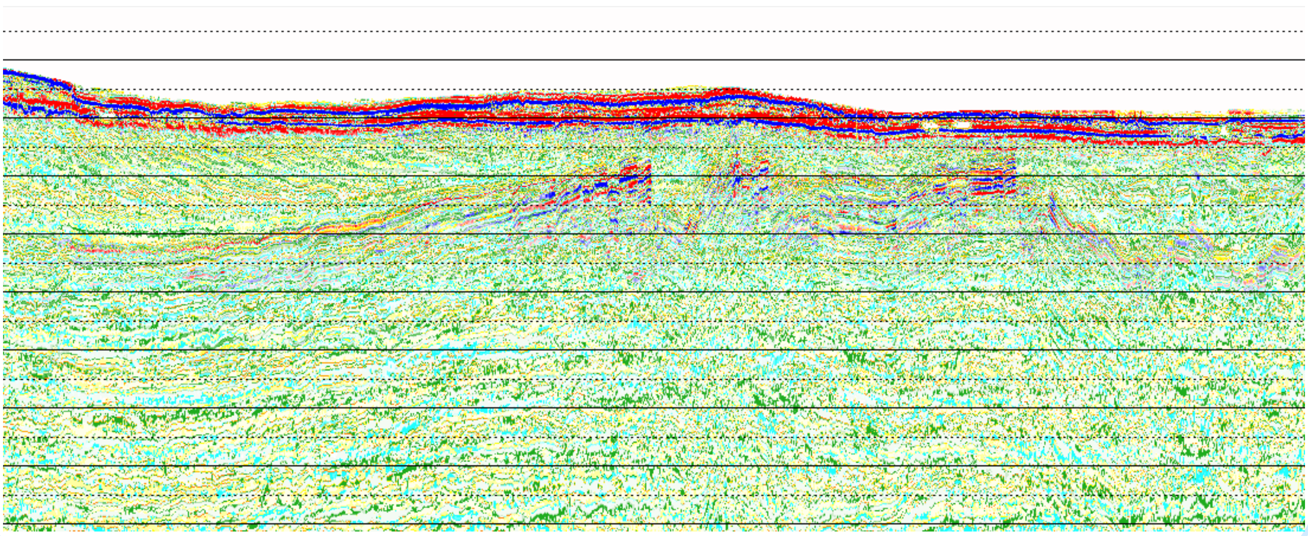


3. Open Color code menu. Load IGT_color_code.txt file in your software, possibly through *Import ascii*.

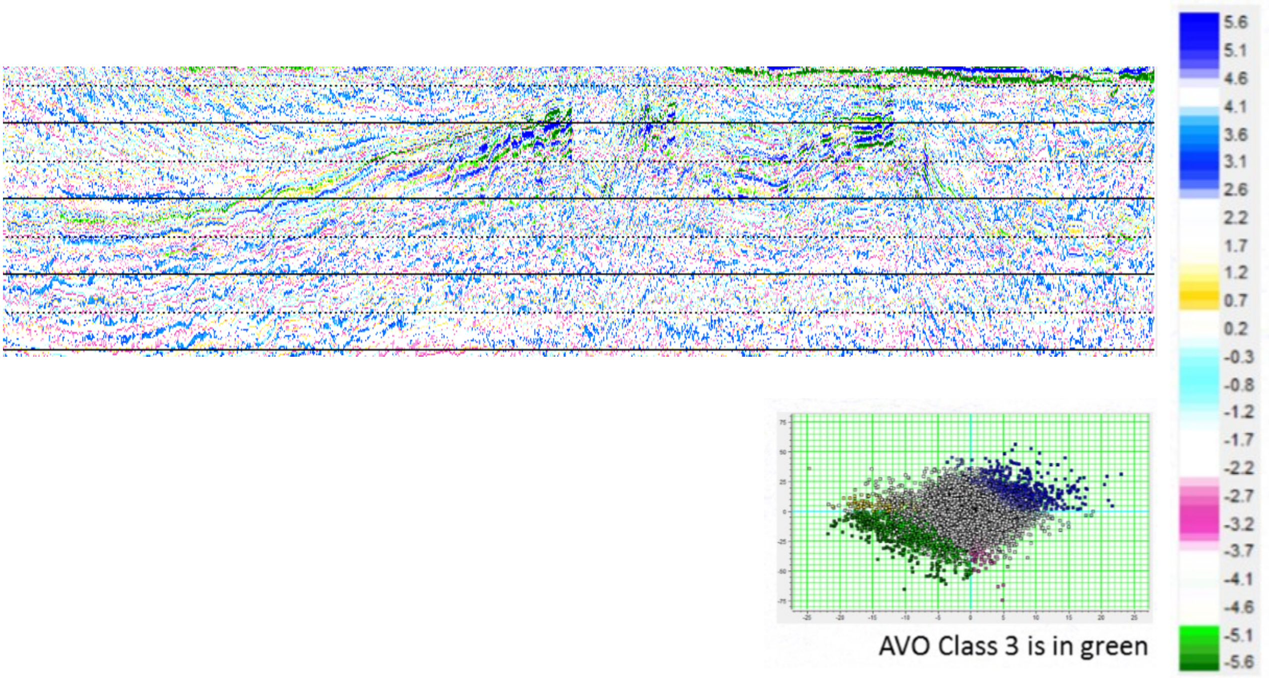


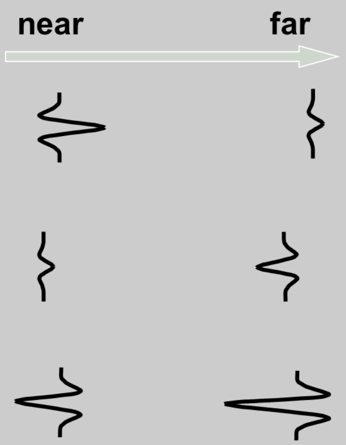
4. Test you scale range by cross plotting Intercept SEGY vs Gradient SEGY, the 3rd cross plot parameter should be IGT Section Amplitudes. Choose window size.

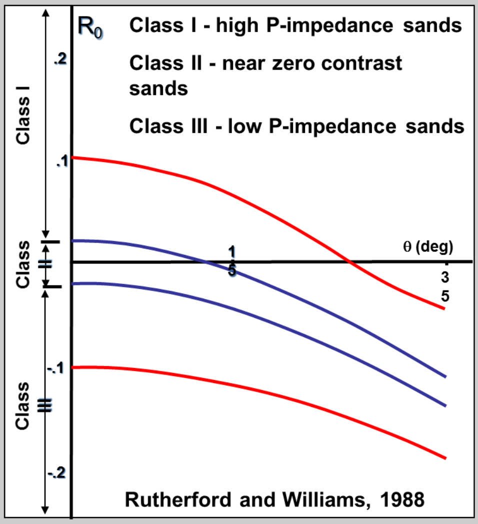


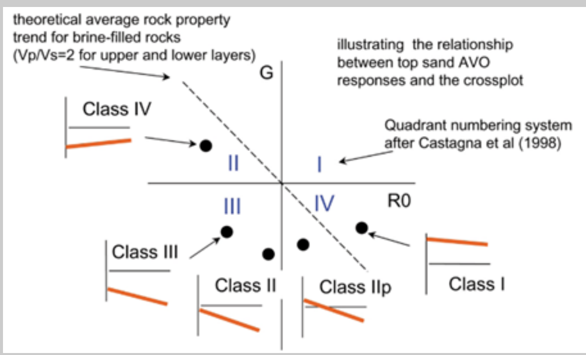


*You can always manually adjust colors in your color code to highlight only that part of the Cross Plot what is necessary, and highlight it by colors which suits you.





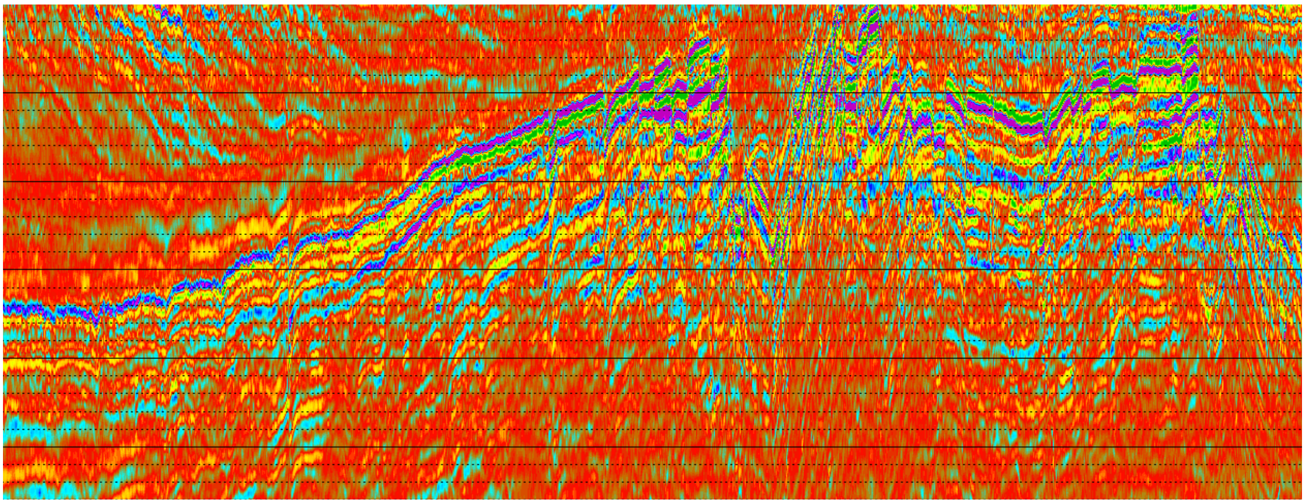




Reminder

8. Density

— (delta Rho) - $\rho=2*(A(t)-C(t))$. *A(t)* is the ideal zero-offset (intercept) trace and *C(t)* is the curvature term [1]. It indicates similar density response in the layers.



Required data

1. Clean PSTM gathers
2. Seismic velocity
3. Well data (Vp, Vs)
4. Horizons

Literature

1. Gelfand, V., Ng, P., Nguyen, H. and Larner, K., 1986, Seismic Lithologic Modeling of Ampli-tude-versus-offset Data, Proceedings of the 56th Annual Meeting of the SEG, Nov. 2-6, 1986, p. 334-336

2. Fatti, J.L., Smith, G.C., Vail, P.J., Strauss, P.J., and Levitt, P.R., 1994, Detection of gas in sandstone reservoirs using AVO analysis: a 3D Seismic Case His-tory Using the Geostack Tech-nique, Geophysics, Vol. 59, p. 1362-1376

3. Jan L. Fatti, George C. Smith*, Peter J. Vail*, Peter J. Strauss*, and Philip R. Levitt, 1994, Detection of gas in sandstone reservoirs using AVO analysis: A 3-D seismic case history using the Geostack technique, Geopysics, Vol. 59, p. 1362-1376*

4. Avseth, P., Mukerji, T., Mavko G., 2010 Quantitative Seismic Interpretation, p. 215-216

5. Taner, M. T., Koehler, F., and Sheriff R. E., 1979, Complex seismic trace analysis, Geopysics, Vol. 44, p. 1041-1063

6. Smith, G.C., and Gidlow, P.M., 1987, Weighted stacking for rock property estimation and detection of gas, Geophysical Prospecting, Vol. 35, p. 993-1014

Software

ProMAX, Seismic Unix, Hampson-Russell