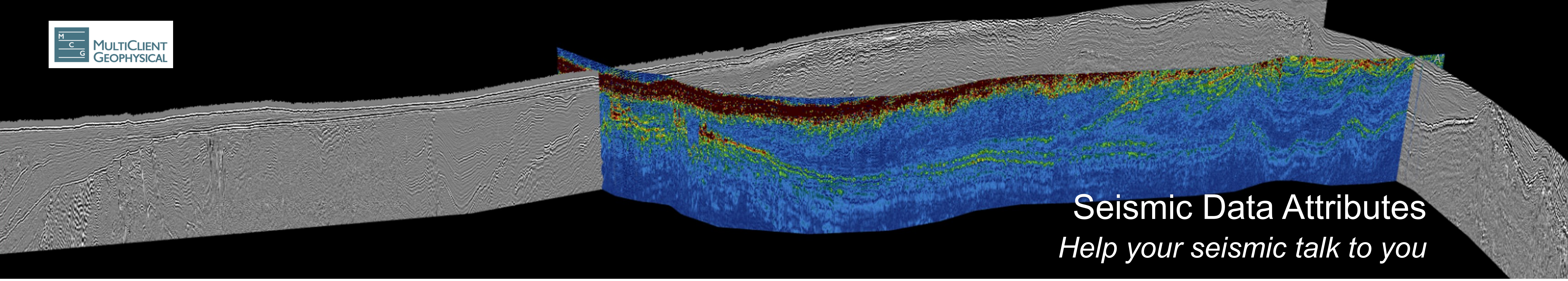

Seismic Data Attributes – new look at the old techniques

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Seismic Data Attributes processing are well know techniques, but not many companies use them for exploration needs. Most on the G&G departments limit their research to AVO or to some simple "screening attributes scan" analysis. Modern software packages include attribute modules which 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.

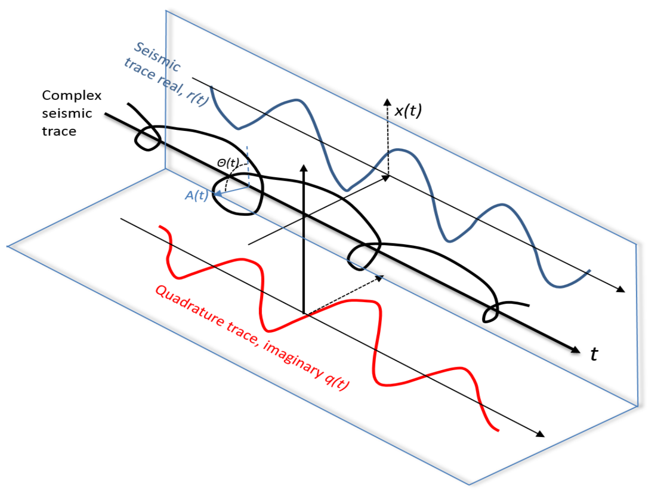
This article is simplified explanation of several Seismic Data Attributes, which PSS-Geo AS normally compute as a part of fully quantitative data interpretation and deliver separately a product package of attributes with color codes and manual.

Some of the attributes that were computed for the MCG Barents Sea Well Tie Survey are shown here.

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 structural and stratigraphic understanding of 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.



Picture 1. Complex seismic trace

Attributes physics and Interpretation

Several attributes were chosen to highlight Lithology and Fluid. The list and description of the attributes are presented below. Some of these attributes are shown on Pictures 3,4,5.

– ***Envelope*** $A(t)=(q^2(t)+r^2(t))^{½}$, $q(t)$ - 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.

– ***Fluid Factor*** (FFr) - $FFr=Rp(t)-g(t)\cdot Rs(t)$, $g(t)=M\cdot(Vs/Vp)$, where M is a slope of liner approximation on Vp vs Vs plot. In the examples shown in this article, to calculate $g(t)$ Castagna sandstone mudrock line* is taken for simplification.

Avseth et al (2010) [3] made a short good and concise description of all the principles for Fluid Factor computation. He summarised that 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.

The strongest negative events in sandstone layers can be considered as hydrocarbon saturated rocks. When $Rp(t)\text{-}g(t)\cdot Rs(t)=0$, it corresponds to brine saturated rocks, with $Rp(t)\text{-}g(t)\cdot Rs(t)<0$, it can be considered as hydrocarbon saturated rocks. Finally, when $Rp(t)\text{-}g(t)\cdot Rs(t)>0$ 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*.

– ***Lithology based fluid indicator *Instantaneous frequency***

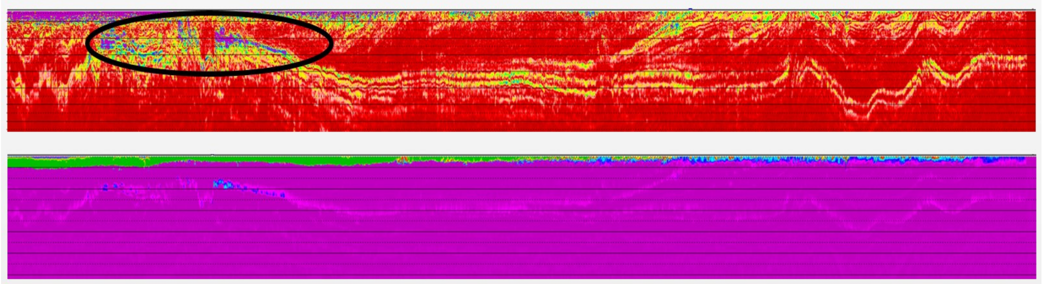
$\omega(t)=d(\theta)/dt$ — instantaneous frequency is the time derivative of the instantaneous phase $\theta(t)$, see Pic. 1. This attribute shows the lower frequencies often seen below gas sands in bright spots: *shadows*. The low-frequencies *shadows* effect is described by Taner et al (1979) [4]. 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.

– ***Lithology based fluid indicator *amplitude weighted frequencies***

Amplitude weighted frequencies is a product of the amplitude envelope (reflection strength) and the instantaneous frequency. Amplitude weighted frequencies of the lithology based fluid indicator section highlights the lowest impedance layers in a more accurate way, see Pic. 3 [4].

Picture 2. The MCG Barents Sea Well Tie Survey.
(Data of MultiClient Geophysical ASA).



Picture 3. A MCG Barents Sea Well Tie line that crosses the Wisting discovery.
Two Seismic Data Fluid Factor based Attributes. Wisting discovery is shown in black oval

– ***Poisson's ration*** (pseudo-Poisson's, introduced by Smith and Gildow as ratio reflectivity [5]). The pseudo-Poison'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.

– ***Density section*** (delta Rho) - $\rho=2\cdot(A(t)-C(t))$. $A(t)$ is the ideal zero-offset (intercept) trace and $C(t)$ is the curvature term [1]. It can be interpreted as an indicator of density similarities over a seismic section. This attribute is only significant at higher offsets.

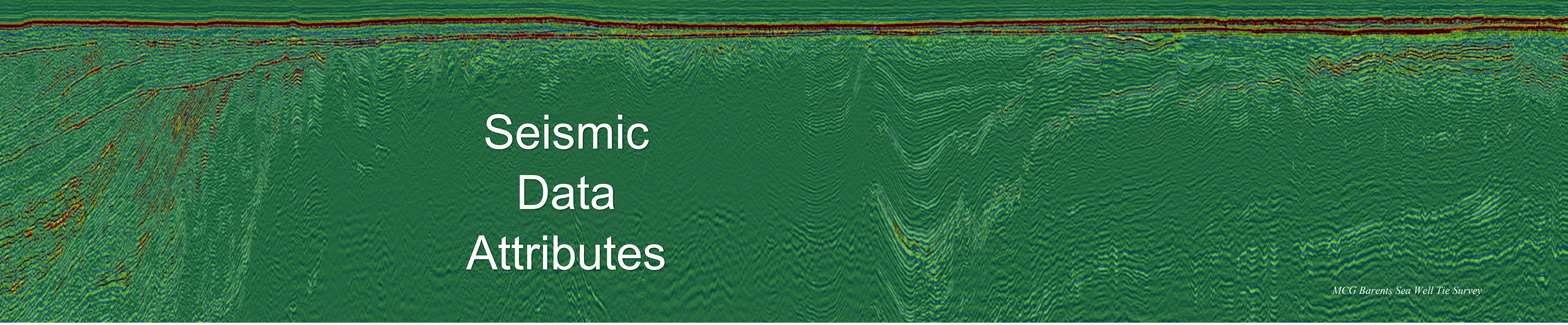
– ***IGT*** (Intercept multiplied on Gradient) section (required spatially calculated color code) – shows seismic section colored by AVO classes, see Pic. 4. ***Intercept*** is the amplitude at zero-offset, and ***Gradient*** is the slopes of the line on amplitudes vs angles of incident plots.

– ***Pay zone*** – the angle of crossover, indicates a polarity reversal effect. Absolute amplitudes decreases with offset until one reaches the crossover angle, flips polarity, and subsequently increases. Events with this response typically appear weak on the stacked section. Nevertheless, this polarity reversal effect has been known to indicate rock properties consistent with pay zone, see Pic. 5.

Examples

The examples below are some attributes displays of the 2D MCG Barents Sea Well Tie line (Data of MultiClient Geophysical ASA, processed by PSS-Geo AS), see Pic. 2. A long East West oriented line was chosen for

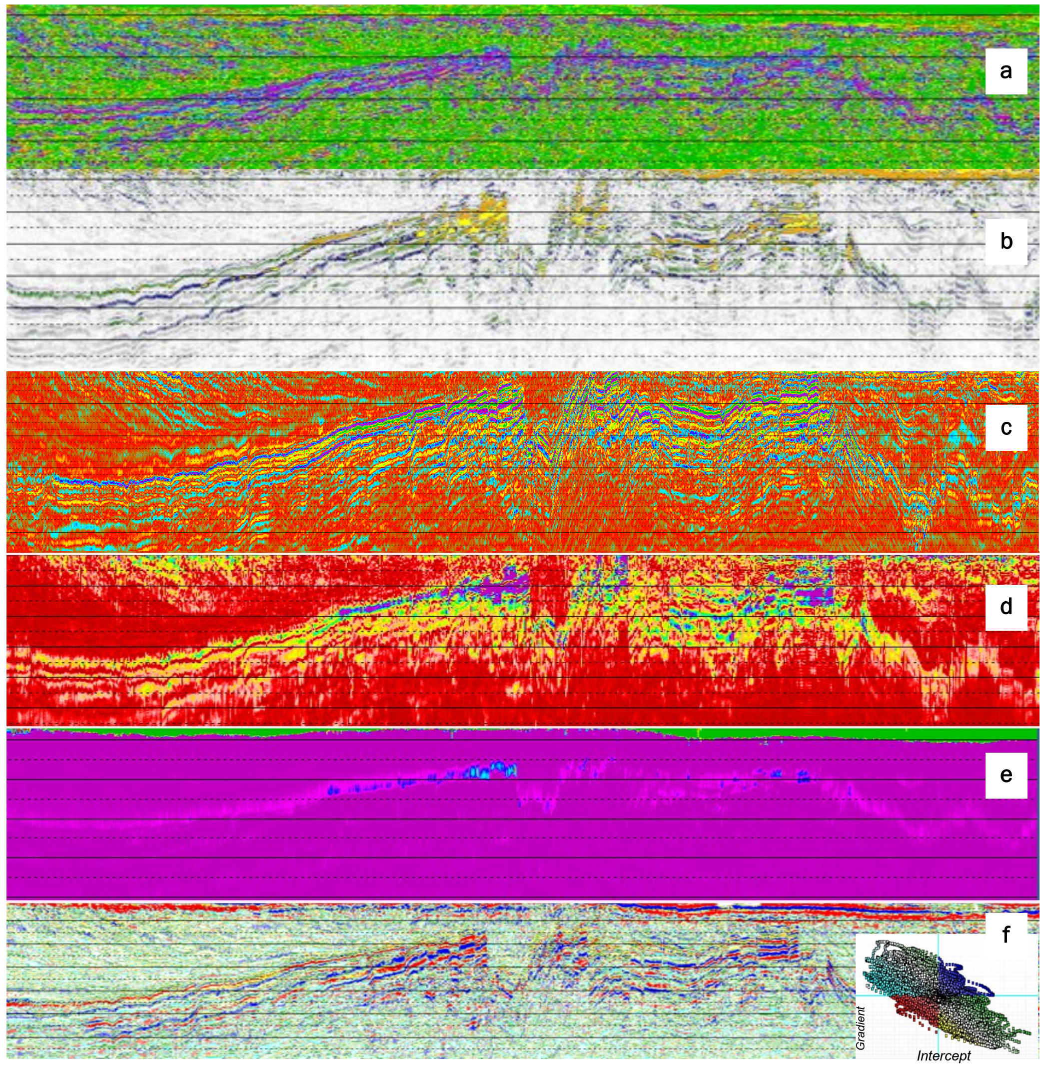
* *Mudrock line is an empirical linear relation between seismic P-wave velocity (Vp) and S-wave velocity (Vs). Introduced by Castagna, J. P.; Batzle, M. L.; Eastwood, R. L. (1985). "Relationships between compressional-wave and shear-wave velocities in clastic silicate rocks". Geophysics 50: 571–581.*



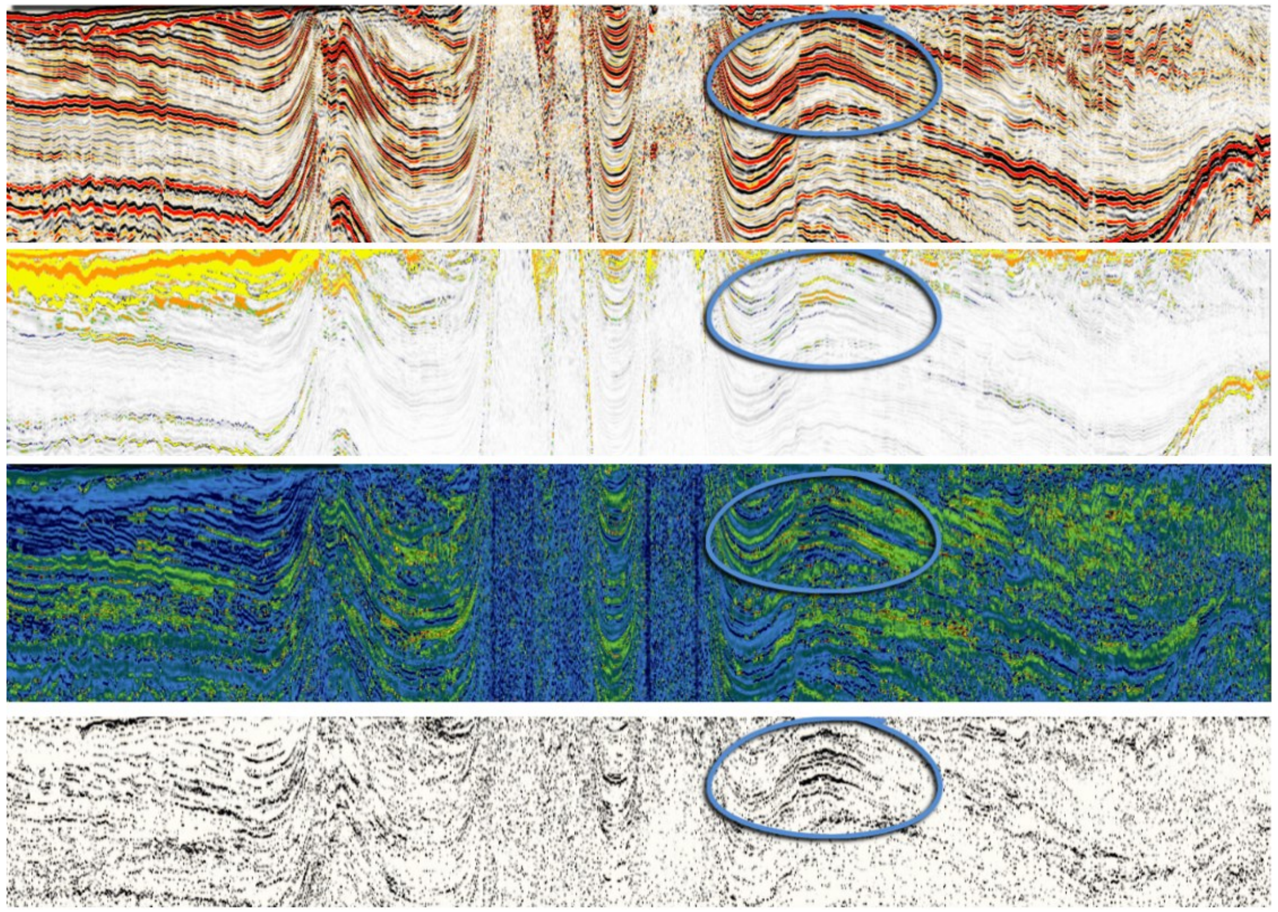
Seismic Data Attributes

crossing the Wisting discovery.
Seismic Data Attributes, described in this article, were calculated for the entire MCG Barents Sea Well Tie Survey. Several reservoirs were highlighted on the Fluid Factor related attributes which were confirmed by other attributes. The reservoirs which were not highlighted on some of the Seismic Data Attributes were postponed from the analysis, see Pic 5. This quick seismic "scan" allowed to define similarity in the rock properties, and possible pores fill.
On Picture 3, amplitude weighted frequencies of Lithology based fluid indicator attribute shows hydrocarbons in purple color. The section below is the integration of the section above. The easiest anomalies that are theoretically supposed to be related to hydrocarbons are in blue.
On Picture 4, several Seismic Data Attributes are shown for a particular area of the Wisting discovery. The top picture *(a)* is Rp (additional attributes, reflection coefficients), showing similarity in reflectivity across the structure. The second picture *(b)* is pure Fluid Factor calculated for Castagna sandstone, as described in *the Attributes physics and Interpretation* paragraph. Negative amplitudes indicate possible hydrocarbons in orange color. Picture *c* is the Density section. Pictures *d* and *e* are amplitude weighted frequencies of Lithology based fluid indicator attribute and its integration. The last picture *(f)* is the IGT section, clearly showing both top and base of the reservoir.
Picture 5 shows a succession of Full Stack and Seismic Data Attributes of another East line from the MCG Barents Sea Well Tie Survey. It is easy to observe "anomalies" matches and mismatches on the presented Attributes.

Summary
Calculated Seismic Data Attributes are the fast scan of seismic data. Most known reservoirs that the MCG Barents Sea Well Tie Survey is crossing in the Barents Sea are nicely mapped.
The attributes are developed to minimize time and risk for exploration, though they should not be used as a final prospect conclusion.
It is important to know that 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 reservoirs can only be done when all hydrocarbon related attributes indicate hydrocarbon at the same event.



Picture 4. Wisting Discovery. From top to bottom: Reflection strength, Fluid Factor, Density, Two Fluid Factor related attributes and IGT section



Picture 5. The MCG Barents Sea Well Tie Survey, East line. From top to bottom: Full Stack, Fluid Factor, Fluid Factor related attribute, Pay Zone

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