SEISMIC TRACE ATTRIBUTES AND THEIR PROJECTED USE IN PREDICTION OF ROCK PROPERTIES AND SEISMIC FACIES

INTRODUCTION:

We define the **"Seismic Attributes"** as all of the measured, computed or implied quantities obtained from the seismic data. Therefore Attributes include complex trace attributes, seismic event geometrical configurations, their spatial and pre-stack variations. We have been able to classify these seismic attributes in a manner that makes their utility more clearly identifiable. This is somewhat different then at the origin of the project. We have used the title 'projected' , because we have not yet proven all of their application. However, some of the attributes, such as the amplitude (envelope), its variation with offset, seismic velocities, and to some degree, the instantaneous phase and frequencies have been used in interpretation for a reasonably long time. In this paper we would like to start with general and specific classification of seismic attributes, then cover their projected use in estimating the rock properties, depositional environment and interpreting seismic facies.
We generally compute attributes from the seismic data represented in time, rather than in depth. Therefore conventional CDP stack sections, DMO applied stack sections, pre-stack or post-stack time migrated sections are equally convenient for attribute computation. The attributes computed from the time migrated sections, due to their more accurate positioning of the reflectors (with respect to the CDP stack sections) may be more advantageous for interpretation purposes. The depth migrated sections, all time related information, such as the frequency, changes to wave numbers and wave-lengths.
It should be noted that, to get the most expected results from seismic attributes, the data has to be processed with care. Special care must be directed to shaping source signatures, removing effects caused by the receiver plantation and array, near surface distortions, time, amplitude and phase distortions.
In preparing this note we have made generous use of James Schuelke's notes. We express our thanks for allowing us to publish them in addition to our comments.

GENERAL CLASSIFICATION:

Based on their direct relations to the interpretive significance they represent, Seismic Attributes are divided into two general classifications;
I) Physical Attributes,
II) Geometric attributes.

PHYSICAL ATTRIBUTES:

Physical attributes are the seismic measurements that directly relate to wave-propagation, lithology and other physical parameters. We divide the Physical attributes into two sub-classes as the pre- and post-stack attributes. Both the pre-stack and the post-stack attributes will have two distinct sub-classes. They are Instantaneous attributes and the Wavelet attributes. Instantaneous attributes are computed sample by sample and indicate continuous change of attributes along the time and space axis. The Wavelet attributes, on the other hand represent characteristics of wavelet and their amplitude spectrum. We compute seismic trace envelope and pick all envelope minima. The distance between two adjacent minima is defined as a wavelet, which could be single wavelet or complex wavelet consisting of several wavelets. The attributes computed at the maximum of the envelope, between two envelope minima, represent the wavelet attribute. This attribute is also called the response attribute. We prefer the Wavelet attribute, because it relates to the wavelet characteristics.

POST-STACK ATTRIBUTES: (INSTANTANEOUS)

These are the attributes computed from the complex (analytic) seismic trace. We use Butterworth type band-pass filters to generate real and imaginary parts of the complex trace. The band-pass filter suppresses very high and very low frequency content of seismic traces to generate a stable Hilbert transformed trace.

1) Real Part of the complex trace,

We generate the complex trace in time domain by a complex Butterworth filter. Real part (zero phase) of the filter generates the real part of the seismic trace. This way both the real and imaginary parts will have the same spectral characteristics. Band limited Butterworth filter satisfies the band limited requirements of the Hilbert transform.

2) Imaginary part of the complex trace. This trace will have identical amplitude spectrum as the real part.

Real and imaginary traces are used to generate the rest of the attributes itemized below.

3) Reflection strength or Envelope amplitude:

- Represent mainly the acoustic impedance contrast, hence reflectivity,
- Bright spots,
- gas accumulation,
- Sequence boundaries, major changes or depositional environments
- Thin-bed tuning effects
- Unconformities,
- Major changes of lithology,
- Local changes indicating faulting,
- Spatial correlation to porosity and other lithologic variations,
- Indicates the group, rather than phase component of the seismic wave propagation,

4) **Time derivative of Envelope:**

- Sharpness of the rise time relates to absorption,
- It is affected by the slope, rather than envelope magnitude, hence indicate sharp interfaces.
- Shows discontinuities,
- It is used in computation of group propagation direction. When compared with phase propagation direction, it may indicate dispersive waves.

4) Second derivative of envelope with respect to time:

- Shows all reflecting interfaces visible within seismic band-width,
- Shows sharpness of events,
- Indicates sharp changes of lithology ,
- Large changes of the depositional environment, even corresponding envelope amplitude may be low.
- Very good presentation of image of the subsurface within the seismic bandwidth.

5) Instantaneous Phase:

- Best indicator of lateral continuity,
- Relates to the phase component of the wave-propagation.
- Can be used to compute the phase velocity,
- Has no amplitude information, hence all events are represented,
- Shows discontinuities, but may not be the best. It is better to show continuities.
- Sequence boundaries,
- Detailed visualization of bedding configurations,
- Used in computation of instantaneous frequency and acceleration,

6) Instantaneous Frequency:

- Corresponds to the average frequency (centroid) of the amplitude spectrum of the seismic wavelet.
- Seismic character correlator,
- Indicates the edges of low impedance thin beds,
- Hydrocarbon indicator by low frequency anomaly. This effect is some times accentuated by the unconsolidated sands due to the oil content of the pores.
- Fracture zone indicator, appear as lower frequency zones.

- Chaotic reflection zone indicator,
- Bed thickness indicator. Higher frequencies indicate sharp interfaces or thin shale bedding, lower frequencies indicate sand rich bedding.
- Sand/Shale ratio indicator,

7) Instantaneous Acceleration:
- Accentuates bedding differences,
- Higher resolution , may have somewhat higher noise level due to differentiation,
- May have some relation to elastic properties of beds.

8) Thin bed Indicator:
- Computed from large spikes of instantaneous frequency, indicate overlapped events
- Indicate thin beds, when laterally continuous,
- Indicate non-reflecting zone, when it appears laterally at random, like 'salt and pepper',
- Fine detail of bedding patterns.

9) Instantaneous Dominant Frequency:
- Similar to the Instantaneous Frequency, except this corresponds to the RMS frequency of the amplitude spectrum (or centroid of the power spectrum) of the seismic wavelet.
- Allows us to compute the seismic band-width.

10) Instantaneous Band-width:
- Represents seismic data band-width sample by sample. It is one of the high resolution character correlators.
- Shows overall effects of absorption and seismic character changes.

11) Instantaneous Q Factor:
- Indicates local variation of Q factor, similar to the relative acoustic impedance computation from the seismic trace. Longer wavelength variation should be computed by spectral division and added to this attribute.
- May indicate liquid content by ratioing pressure versus shear wave section Q factors.
- Indicate relative absorption characteristics of beds.

12) Instantaneous Relative Acoustic Impedance:
- This trace is the result of simple integration of the real part of the complex trace. It represents the approximation to the high frequency component of the relative acoustic impedance.

13) Normalized Amplitude:
- It is the cosine of the instantaneous phase angle. It represents continuity and helpful in lateral continuity direction determination. It will have no amplitude information.

14) Envelope modulated Phase:
- This is the instantaneous phase display with the intensity of the colors controlled by the trace envelope magnitude. Higher amplitudes will be intense color, low amplitude will have less intense pastel shades. This display will show the detail of the phase variation of the strong events, without the interference of weaker events as in the instantaneous phase display.

PRE-STACK ATTRIBUTES:

1) RMS velocities of reflectors :
- This may be Time Migration velocity analysis, independent of major influence of dips. This is used for sand/shale ratios estimation, high pressure shale zone detection, major lithologic change detection, and etc.
- Zero offset pressure-wave seismic section,
- Zero offset shear-wave seismic section estimation,
- Group velocity, phase velocity decomposition,
- Trace envelope amplitude variation with respect to offset,,
- Instantaneous frequency variation with respect to offset,

GEOMETRICAL ATTRIBUTES:
- Dip and azimuth of maximum coherency direction,

- Coherency at maximum coherency direction,
- Minimum coherency directions,
- Event terminations,
- Picked horizons,
- Fault detection,
- Zones of parallel bedding,
- Zones of chaotic bedding,
- Non-reflecting zones,
- Converging and diverging bedding patterns,
- Unconformities.

SOME COMBINED USE OF ATTRIBUTES:

- Chaotic reflection zones,
- Combined geometrical and physical attributes for sand/shale zone detection
- Carbonate layer detection,
- Validity of stack section estimation,

WAVELET ATTRIBUTES:

These are the attributes computed at the peak of the envelope, which represent the attributes of the wavelets within a zone defined by the trace envelope minima. These attributes indicate spatial variation of the wavelets, thus relate to the response of the composite group of individual interfaces below the seismic resolution.

(This is an incomplete report. It is enclosed for your information. We wish to show the validity of the suggested usage of the attributes by actual experimentations.)