Attenuation and velocity of acoustic waves - indicators of reservoir parameters of the formation

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Attenuation of elastic waves in general approach is a complex effect due to absorption of elastic energy (internal attenuation) and due to dissipation of elastic energy (apparent attenuation). The first type of attenuation depends on lithology and on reservoir parameters; especially saturation of pore space plays the magnificent role in this case. The second type of attenuation is associated with structural parameters of formation like thin bedding, which cause changes of velocity and density of rock medium.

Elastic parameters of the rocks depend also on porosity and features of pore media. Longitudinal wave velocities of rocks saturated with water, oil and gas relate as follows: $V_{PW}>V_{PO}>V_{PG}$, while shear wave velocities of saturated rocks behave reciprocally: $V_{SW}<V_{SO}<V_{SG}$. Decrease of shear velocity from gas saturated rock through oil saturated rock to gas saturated rock is a result of density increase and constant compressibility of rock medium.

Attenuation of seismic waves and acoustic waves cause the decrease of amplitudes. The influence of seismic noise on the amplitudes is similar. The current challenge is how to distinguish the real structure (useful signal) from non-geological features (noise). The characteristic of seismic noise is very important in the investigated region because it protects before misinterpretation.

Well logs are helpful in distinguishing between real and apparent anomalies in seismic wave field. Dipmeter and acoustic scanner (acoustic borehole wall imaging) play significant role in identification of geological structures. Acoustic full waveforms are also important recordings for determination of real elastic features of rocks. Readings of the above mentioned methods depend also on reservoir parameters of rock medium.

Compressional wave velocity calculating from longitudinal wave slowness (recorded in traditional sonic log) is relatively simple operation in comparison to shear wave velocity determination. There are elaborated methods to obtain both of velocities basing on acoustic full waveforms [Kimbal, Marzetta, 1984; Bała, Jarzyna, 1998]. Attenuation of acoustic waves may be also obtained from the acoustic full wavetrains on the base of following relations between amplitude ratio and damping coefficient:

$$\ln (A_2(R_2f)/ A_1(R_1f)) = -\alpha(R_2 - R_1) \quad \text{or} \quad \ln (A_2(R_2f)/ A_1(R_1f)) =-\pi f(T_2 - T_1)/Q$$

where T_2 and T_1 are the arrivals of acoustic wave to the far and near receivers (placed at the distances R_1 or R_2 from transmitter, respectively), f means frequency and Q is quality factor [De et al., 1994]. We can use the amplitude spectra ratio instead of amplitude ratio and obtain the following formula:

$$G_2(R_2f) = KG_1(R_1f)\, e^{-Af}$$

where factor A is a function of the attenuation on the distance R_2-R_1 not dependent on frequency, and K is a coefficient associated with acoustic impedance of rocks, not dependent on frequency, too.

The interpretation was made in two lithological groups: shaly-sandstones and carbonates. The acoustic full wavetrains were used to determine the compresional wave velocity: V_p, shear wave velocity: V_S and Stoneley wave velocity V_{St} of the formations. The attenuation factors A and K were also calculated basing on acoustic full waveforms. The correlation between reservoir parameters (saturation, porosity and permeability obtained from well logs and from core data) and velocities and attenuation factors were obtained. The mutual dependence between two groups of parameters: elastic and reservoir - is clearly visible.

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2. Kimball, Ch.V., Marzetta T.L., 1984 - Semblance processing of borehole acoustic array data. Geophysics, vol.49, Nr3, 274-281
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