Design Analysis of the Raymer–Hunt-Gardner Algorithm and Modification for Shaly Sands

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Time average equations of MRJ Wyllie and Raymer et al have been under criticism for their inefficiency in dealing with the shaly sand acoustic porosity. As such the prevailing practice is to create regression algorithms that correlate acoustic velocity to porosity. Present work presents a modification of the Raymer-Hunt-Gardner algorithm to make it a universal velocity-porosity transform applicable to shaly sands.

Design analysis of the Raymer-Hunt-Gardner algorithm has revealed that porosity quadratic is implicit in it with scope for generalization to cover the shaly sand p-wave phenomena.
Accordingly RHG relation has been generalized as

$$\phi^2 + \phi\left(\frac{\Delta t_{ma}}{\Delta t_f} - \omega\right) + \left(1 - \frac{\Delta t_{ma}}{\Delta t_{log}}\right) = 0$$

to serve as a porosity algorithm to the shaly sand P-wave velocities. Porosity first order coefficient is modified by replacing 2 with w, defined as a variable that addresses the clay content of the rock. Modified algorithm has been applied to a large data set of sandstone formations and w is found to be in the range 1.0 to 10 or even greater subject to the degree of acoustic anomaly presented by the samples. For reasonably good porosity and low clay content w (Omega) is found to be in the range 1.7 to 3 for sandstone velocity data of Han at 40 MPa pressure. Application of the generalized algorithm to to account for the scatter of the Dt-f relation has shown that w is an efficient variable to keep the residual a minimum by playing the role of a surrogate parameter that accounts for all the factors that have escaped modelization.

Further, the Modified Raymer-Hunt-Gardner algorithm as above has been shown to be of universal application by defining the variable omega in petrophysical terms as:

$$\phi^2 + \phi\left(\frac{\Delta t_{ma}}{\Delta t_f} - \left(\frac{\Delta t_s}{\Delta t_p}\right)^x\right) + \left(1 - \frac{\Delta t_{ma}}{\Delta t_{log}}\right) = 0$$

Algorithm as above can be tailor made to meet the specific shaly sand environment by fixing the *Vp/Vs* exponent *x* appropriately based on shale indicator logs or laboratory studies. It is shown that in terms of shale content omega may be defined as

$$\omega = \frac{V_p}{V_s} + \rho_b C_{frac} = \left(\frac{V_p}{V_s}\right)^x$$

For Han's data, the Omega may be comfortably derived as (Vp/Vs) + rb* C_{frac} where C_{frac} is the volume fraction of clay/shale. It has been shown that in combination with the density log and a clay indicator such as GR, P-wave velocity can be used for deriving precise porosity values. Experience also suggests bulk density may be substituted for omega to obtain porosity values comparable to density-neutron porosity in shaly sands. Modified equation can be applied to derive porosity from S-wave velocity also using Dtma (shear) and retaining the p-wave velocity of the fluid. It is likely that omega may emerge as a parameter capable of characterizing the shaly sands in a meaningful manner. Value addition from acoustic logs and especially, Dipole Sonic Shear Imager (DSI) log will be greatly improved by the new method suggested.

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