Density prediction using *P*- and *S*-wave sonic velocities

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Introduction

Gardner et al. (1974) conducted a series of controlled empirical studies and determined a relationship between *P*-wave velocity, V_p, and density, ρ, that has long been used in seismic analysis:

$$\rho = aV^b \qquad (1)$$

where ρ is in g/cm^3, a is 0.31 when V is in m/s and is 0.23 when V is in ft/s and b is 0.25. Major sedimentary rocks generally define a narrow corridor around this prediction. The major deviations from this trend are anhydrites, coals, and salts. Lindseth (1979) used Gardner's empirical data to derive the following relationship between acoustic impedance and velocity:

$$\rho V = (V-c)/d \qquad (2)$$

where ρ is in g/cm^3, V is in ft/s, c is 3460 and d is 0.308. This work investigates the use of Gardner's relationship, Lindseth's relationship, and a hybrid relationship (sum of the two previous equations), with both *P*-wave and *S*-wave velocities to predict density. The log data studied in this report are taken from the 12-16, 09-17 and 08-08 wells within the Blackfoot field located near Strathmore, Alberta. The Glauconitic member of the lower Cretaceous is of particular interest here. Within it are a shale-filled channel and a porous sand-filled channel. The sand-filled channel is the producing unit in this area. We are interested in determining whether density estimation can be improved by the use of *S*-wave velocity, V_s, and how *S*-wave impedance is related to *S*-wave velocity.

Methods and results

V_p versus ρ plots and V_s versus ρ plots are generated from the well logs. We use V_s in Gardner's and Lindseth's relationships to predict density. Although these relationships were originally developed with *P*-wave data, we find that in the Gardner's case V_s fits the expected equations for density predictions as well or better than V_p. A polynomial that best fits the data in a least-squares sense is applied to these relationships to estimate the coefficients a, b, c and d. Using the estimated relationships, standard deviations and variances were calculated. We find that standard deviation and variance are generally smaller for V_s than for V_p in these density models for two of the three wells analyzed. Table 1 summarizes these results.

Conclusions

We find that V_s can be used to predict density and there is a relationship between *S*-wave impedance and velocity. For two of three wells investigated, V_s has smaller standard deviations and variances in Gardner's and Lindseth's relationships than does V_p.

References

Gardner, G.H.F., Gardner, L.W., and Gregory, A.R., 1974, Formation velocity and density – the diagnostic basics for stratigraphic traps: Geophysics, 39, 770-780.

Lindseth, R.O., 1979, Synthetic sonic logs – a process for stratigraphic interpretation: Geophysics, 44, 3-26.

Table 1: Summary of coefficients and statistical analysis for density models using V_p and V_s (ft/s).

Well Name	12-16		09-17		08-08	
Velocity	V_p	V_s	V_p	V_s	V_p	V_s
a $\rho=aV^b$	0.238	0.370	0.208	0.214	0.190	0.371
b	0.249	0.218	0.264	0.280	0.271	0.214
Gardner's Variance	0.0014	0.0015	0.0013	0.0012	0.0020	0.0012
c $\rho V=(V-c)/d$	2646	1089	2509	1278	2991	1183
d	0.313	0.323	0.313	0.313	0.313	0.333
Lindseth's Variance	0.0091	0.0094	0.0078	0.0067	0.0129	0.0070

(1998) Geo-triad '98: Abstracts: Plenary, Oral, Posters, Core Workshop