Shear Velocity Prediction in the Norwegian Sea

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Abstract

Well-bore derived measurements provide a link through rock physics, to the seismic domain. Shear wave velocity log data is important for many aspects of seismic modeling, including offset synthetic seismogram generation, and half space modeling for AVO analysis. Due to the relatively recent advent of shear wave velocity logs (V_S), V_S data is in many instances missing or unreliable. However, as compressional velocity logs (V_P) are widely available a local empirical transform relating V_P to V_S would be useful. Several authors have published methods for predicting shear wave velocities in the absence of measured data, including Greenberg and Castagna (1992) and Krief (1990). These published models require, P-wave velocity information, but also accurate porosity, mineralogical content, fluid content, and associated elastic parameters. Han (1986) related V_P to V_S using empirical regressions of ultrasonic velocities, of 80 well-consolidated Gulf Coast sandstones. Here in, we present a simple method for determining an empirical relationship between V_P and V_S, and apply that relationship to a regional study in the Norwegian Sea.

Discussion

Our overall objective is to improve the reliability and accuracy of seismic to well ties in the Norwegian Sea, as well as to evaluate the response of synthetic seismograms to the effect of varying potential reservoir fluids. A main component is a rational rock physics model that allows for the robust prediction of shear velocity. Proper pre-conditioning of the well log data through rigorous log analysis is necessary to build a log suite that can be used in rock physics modeling (i.e. fluid substitution or porosity modeling) and synthetic seismogram generation. Shear wave information is vital for both. If shear velocity information is missing, V_S must first be predicted.

The Norwegian Sea study (Figure 1) included some 30 wells, 9 of which had a measured shear velocity log. All logs were edited for spurious data (cycle skips, severe wash-outs, etc.). To evaluate the relevance of an empirical relationship between of V_P with V_S, the ratio of V_P and V_S is plotted against the V_P values (Figure 2). The data from the 9 wells is plotted for the entire well for each well, and exhibits a correlation between V_P and V_S. Superimposed on the Norwegian Sea data are trends from Greenberg-Castagna (1992), and Han (1995). There is considerable scatter in the Norwegian Sea data; this non-uniqueness can be largely attributed to differentiation in lithology, and fluid saturation content. The overall trend indicates that the determination of an empirical model to predict V_S from V_P should be valid.

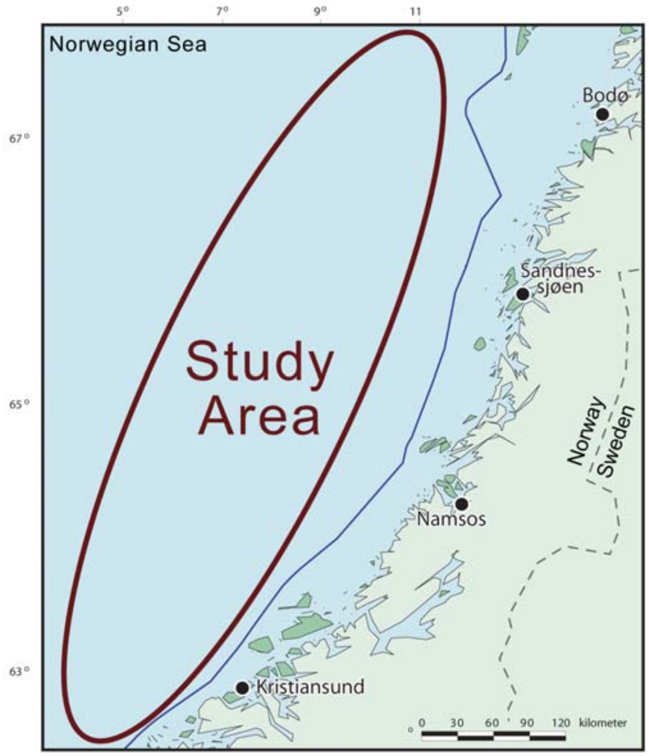

Figure 1. Study area in mid Norwegian Sea.

The derivation of a useful V_S predictor requires that the effects of lithology and fluid saturation be examined. The measured V_S values were cross-plotted against the measured V_P values, using volume shale (*VSH*) as a discriminator for each well. The *VSH* curve values were derived primarily from gamma ray, then neutron, density, and photoelectric effect curves where available, and calibrated to mud log and core data. An example is shown in Figure 3, which is from the 6707/10-1 well. A simple linear regression technique was applied for shale rocks ($VSH \geq 50\%$), brine saturated sandstones ($VSH < 50\%$ and water saturation $\geq 70\%$), and gas saturated sandstones ($VSH < 50\%$ and water saturation $< 70\%$) for each well. There were too few oil-saturated sandstones to generate a relationship. The correlation coefficients (r^2) for the regressions ranged from 0.95 – 0.98, indicating strong linear correlation between V_P and V_S for the studied wells. The similarity of individual regression results, indicated that a singular empirical relation could be used to predict V_S from V_P for a given the lithology. The resulting V_S predictor for the area is given in the form:

V_S shale = $(0.76 \times V_P) - 2854$

V_S wet sand = $(0.80 \times V_P) - 3060$

V_S gas sand = $(0.70 \times V_P) - 1000$

Where velocity is given in FT/S.

Greenberg and Castagna (1992) and Krief' (1990) methods were also used to generate V_S curves for the wells, as a quality control measure. Figure 4 exhibits the well log curves from the 6707/10-1 well. The curves shown are a graphical example of the relationship of the various predicted V_S curve values with the measured V_S values. The local V_S estimator algorithms were applied to all the wells in the study area that lacked V_S curves. Moreover, in wells possessing measured V_S values, where those values were missing, the estimator was applied. The resulting complete density, V_P, and V_S can be used to for acoustic modeling.

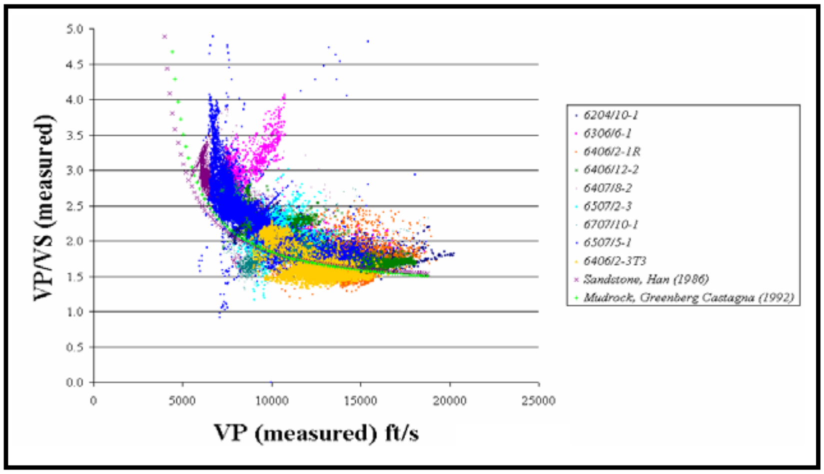

Figure 2. Vp/Vs ratio plotted against Vp for 9 wells in study area, overlain by Han 1986, and Greenberg/Castangna 1992 trends.

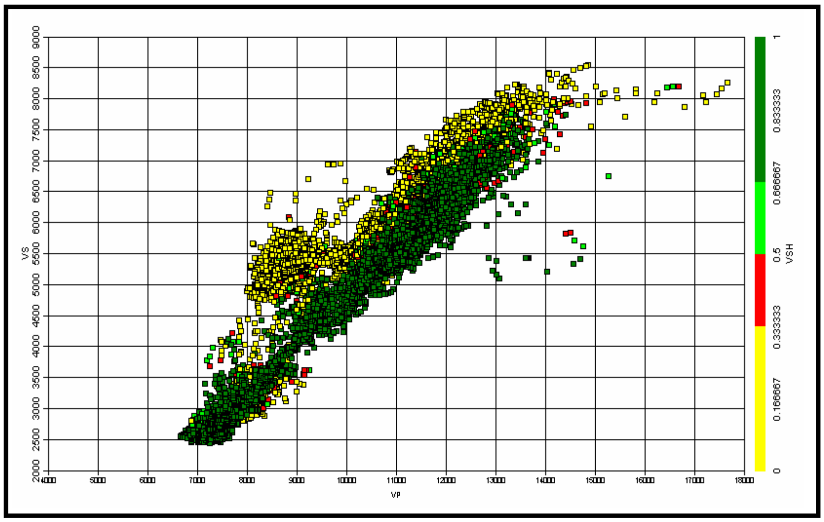

Figure 3. Measured Vs plotted against Vp with volume shale as discriminator "color coded" for 6707/10-1 well.

Summary

Synthetic seismic modeling requires continuous curves of density (*RHOB*), compressional wave velocity (V_P), and shear wave velocity (V_S,). Many times the V_S curve values are missing or unreliable. A locally derived V_S estimator could be advantageous for several reasons (similar rock types, similar digenetic history, similar pressure and temperature regime, etc.) over a published estimator from a different basin. Rational rock physics models provide a link between well-bore derived measurements and the seismic domain. In wells possessing both measured V_P and V_S data, simple linear regression models can provide the empirical algorithms to derive V_S in wells without measured V_S values. Trends between V_P and V_S were segregated by lithology and fluid content. The resulting empirically derived V_S values were then applied to the remaining wells in the regional database, and used for acoustic modeling.

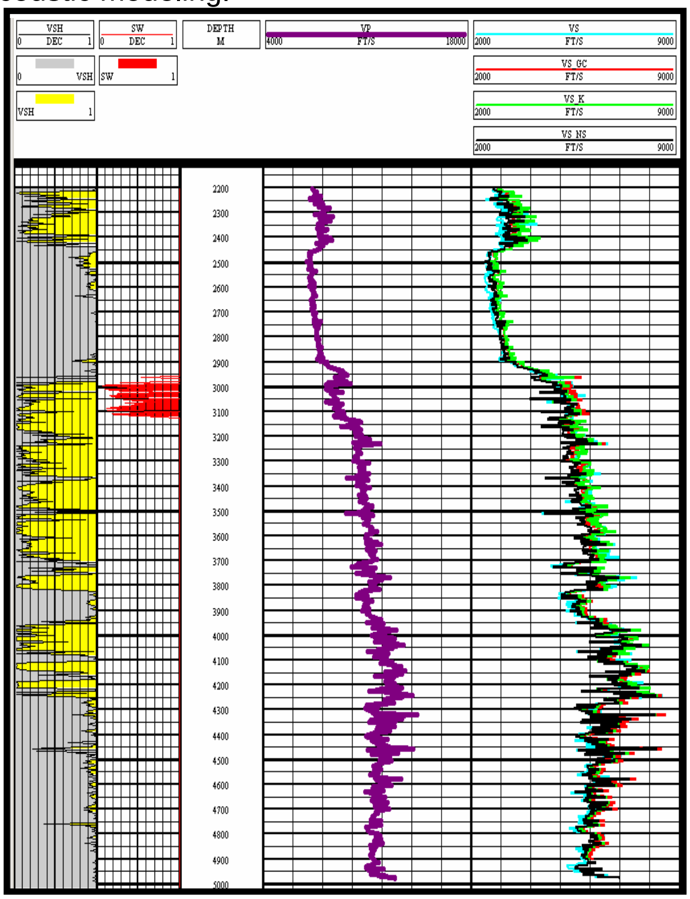

Figure 4. Well log from 6707/10-1 well exhibiting multiple Vs curves.

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