A New Method in Preparing Laboratory Core Acoustic Data for Assisting Seismic-based Reservoir Characterization

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Current development in reservoir characterization has demonstrated the trends towards maximizing the use of seismic survey data for mapping rock physical properties such as porosity and water saturation. Knowledge upon the relation between the two rock physical properties and seismic attributes is, therefore, a prerequisite in order to enable the deducting of porosity and water saturation from acoustic (i.e. seismic) data. Previous efforts (e.g. Widarsono and Saptono, 1997;Widarsono and Saptono, 2000) have been spent in modeling relation between seismic output (e.g. P-wave velocity and Poisson ratio) and the two rock physical properties based on results of standard well log analysis (i.e. porosity, water saturation, sonic velocity, density, and shale fraction). However, the works also show that the common absence of rock-matrix dry elastic properties (i.e. dry bulk and shear modulus) in well log data has prompted the need to perform a series of laboratory acoustic measurement.

To fulfil the requirement for the data, a new procedure for processing and preparing data of laboratory acoustic measurements on cores has been established. In contrast to the common practice, i.e. the needed data is obtained from direct laboratory acoustic measurement on dry core samples, the proposed procedure includes similar measurement on core samples at various water saturation levels and at simulated reservoir condition. Mathematical modelling is then applied on the resulting data, from which rock matrix dry properties are produced, hence indirect measurement. The data is can then be used in preceding modelling on the well log data mentioned earlier. This procedure has at least two advantages when compared to the conventional/direct method. Firstly, in case of inappropriate rock matrix data for the modelling on the well-log analysis results, the data can be adjusted more easily and justified since the core also possesses water saturation data (apart from porosity and P-wave velocity) to compare with the corresponding parameter from well log. Secondly, although according to the theory of elastic wave propagation changes in acoustic velocities of liquid-saturated rocks are caused by the liquids’ compressibility, as have been concluded by some investigators in the past through their experiments (e.g. King, 1984), other causes are also considered potential. Johnston et al (1979), for instance, argued that fluids tend to lubricate rock grains resulting in higher attenuation (i.e. lower viscosity). In compliance to this possibility it is, therefore, considered more appropriate to obtain the ‘effective’ rock matrix data through the proposed procedure than from the direct measurement on dry cores.

To support the application of the new approach a series of laboratory P- and S-waves measurements has been conducted on core samples of different porosity values taken from an oil sandstone reservoir in Central Sumatra, Indonesia. Careful preparation was made on the samples. Synthetic brine with salinity slightly higher than formation brine was used for preventing clay swelling. The carefully prepared measurements were made at a simulated overburden pressure. Various water-oil saturation levels using synthetic oil and brine with their physical properties simulated at reservoir (P and T) condition. Several parameters have been derived from the transit time data such as P- and S-wave velocities, Poisson ratio, bulk modulus, and Young's modulus. Examples are presented in Figures 1 and 2.

Following the proposed procedure the steps taken in the data processing are as follows

1. Measurement in standard manner data of porosity, water saturation, density, P-wave and S-wave velocities, and hence the rock mechanical properties.
2. Modelling of relation between physical properties (e.g. porosity and water saturation), P-wave velocity and Poisson ratio using a combination of Gassmann acoustic velocity model and the theory of elastic wave propagation. The model relation is presented in Figure 3.
3. The plot between water saturation values proves validation of the model, involving iteration, from both model and observation (Figure 4). The 'effective' rock matrix bulk and shear modulus used in the validated model is then used in the modelling on well log data.
4. Similar modelling on well log data taking into acount the effect of variations in density and shaliness. Adjustment on the 'effective' rock matrix data is made on the line of correlating P-wave velocities from well log and core, for the same pairs of porosity and water saturation. The correlation is presented in Figure 5.
5. Confirmation and validation following step 3 (Figure 6), which results in the modelled relation, ready to be used in interpreting seismic attributes. An example of the relation (in form of a cross-plot) for two matrix density and two shale fraction ranges is presented in Figure 7.

The new procedure proposed appears promising, and by applying this, the cross-plots can be considered ready to support effort to determine porosity and fluid saturation distribution derived from seismic data.

References

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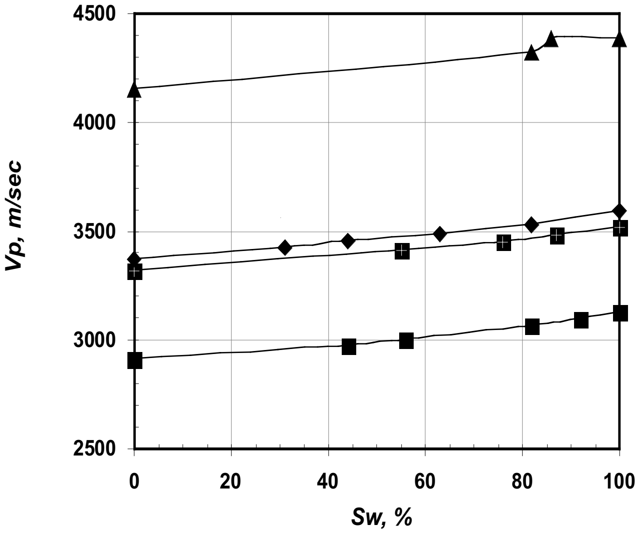

Figure 1.
Example of acoustic measurement (*Vp* vs *Sw*).

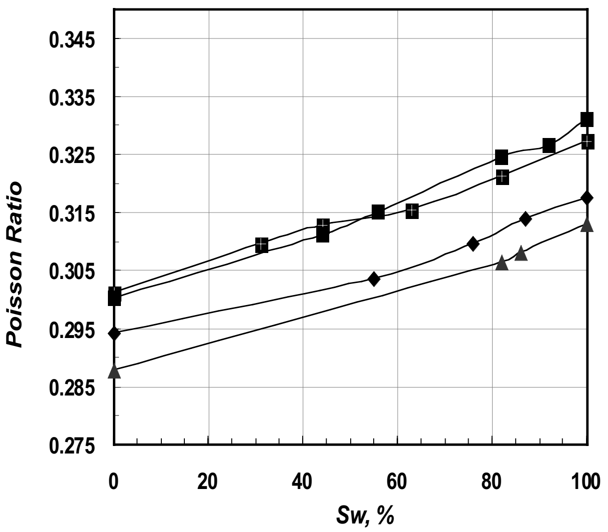

Figure 2.
Example of acoustic measurement, (*Poisson ratio* vs *Sw*).

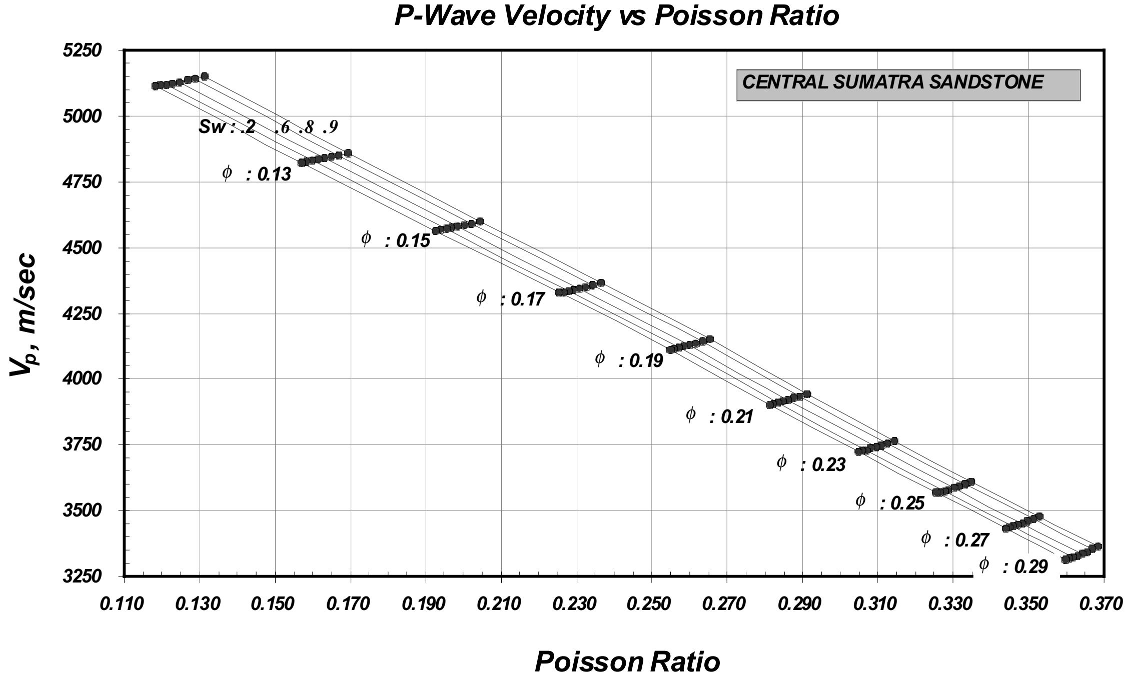

Figure 3. Crossplot as the result of mathematical modeling for the Central Sumatra sandstone (laboratory condition).

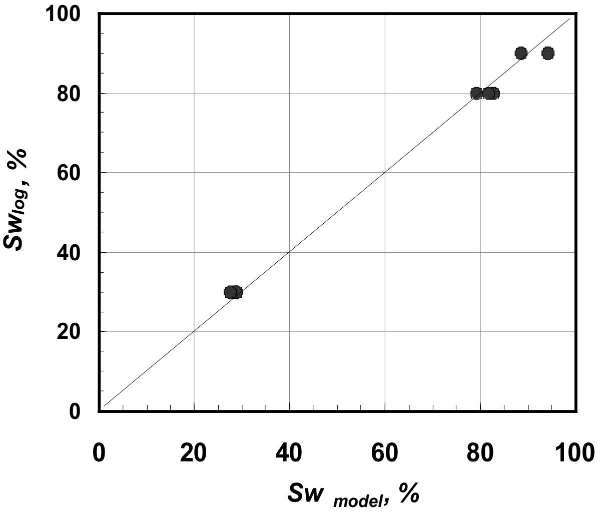

Figure 4.

Model validation (Sw_{lab} vs Sw_{model})

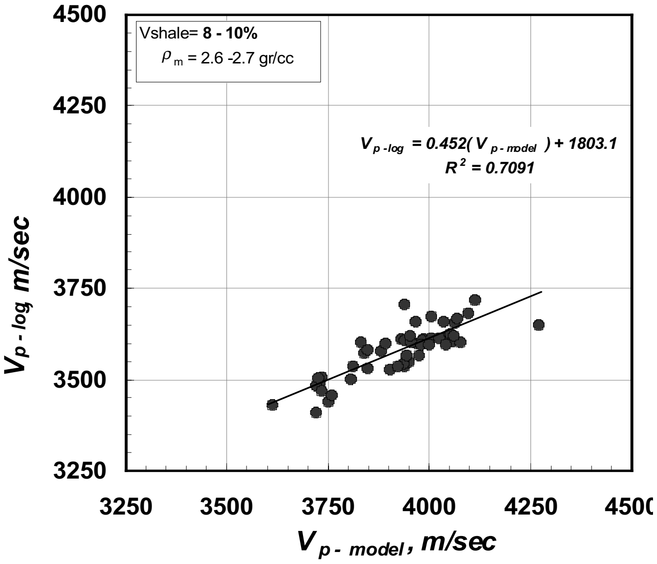

Figure 5.

Vp- $_{model}$ vs Vp- $_{log}$, used for conversion/calibration into situ condition. Vshale= 8 - 10 %, ρ_m = 2.6 - 2.7 gr/cc

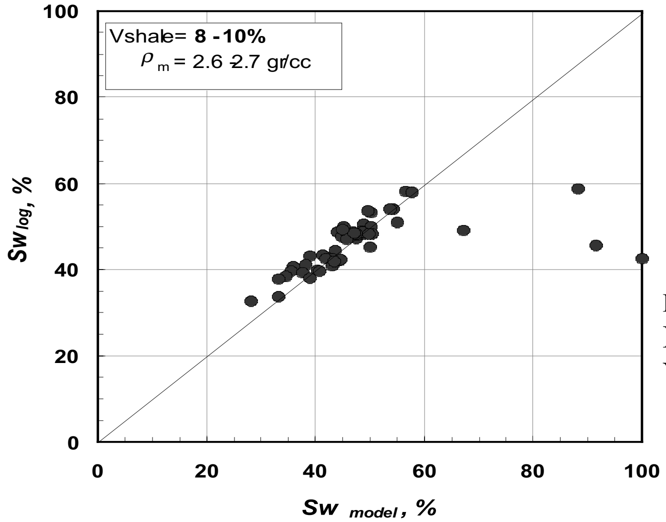

Figure 6.

Model validation (Sw_{log} vs Sw_{model}).
Vshale= 8 - 10 %, ρ_m = 2.6 - 2.7 gr/cc

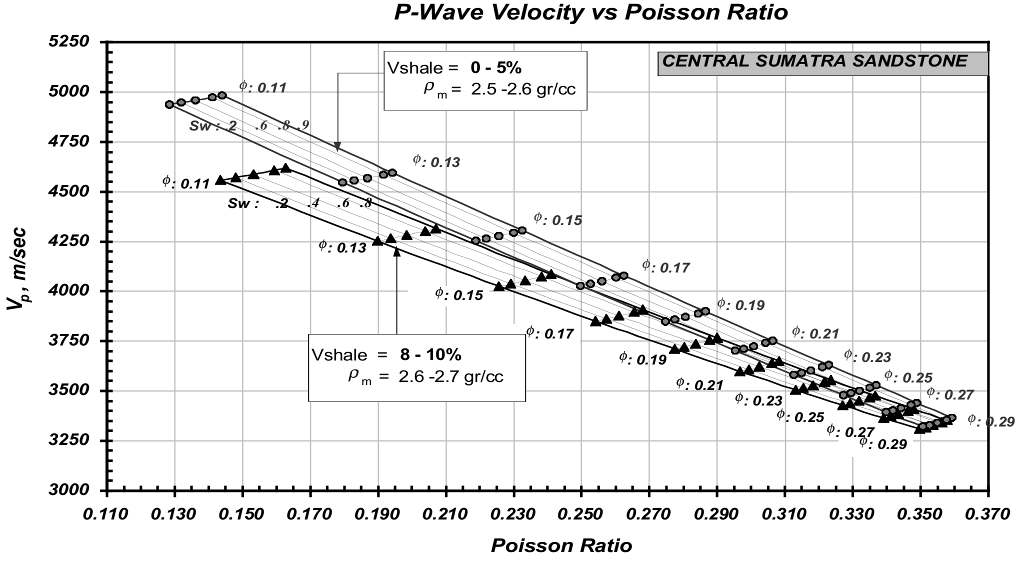

Figure 7.

Examples of the resulting crossplots (in situ condition) for the Central Sumatra sandstone, with acomodating effect of shaliness: Vsh = 0 – 5 %, ρ_m = 2.5 - 2.6 gr/cc and Vsh = 8 – 10 %, ρ_m = 2.6 - 2.7 gr/c