

Rock Physics of Marls

Jack Dvorkin (Stanford University), Joel D. Walls (Rock Solid Images), Gary Mavko (Stanford University)

Summary

Rock physics analysis of well log data in marl intervals shows that distinctive relations exist between the elastic propagational properties and porosity of this rock and also between V_s and V_p . In the V_s versus V_p cross plot, the marl data fall onto an experimental V_s versus V_p trend originally designed for calcite. As the amount of shale in marl increases, the data move along the calcite line and intersects the shale line. Although the impedance of marls may vary within a large range, depending on the concentration of calcite, their Poisson's ratio varies only within a small interval between 0.3 and 0.33.

Introduction

In spite of their common occurrence, very little detailed rock physics analysis is available for shaly carbonates known as marls. In this paper, petrophysical analysis was performed on two well logs from the North Sea. The lower part of these two wells was identified as marl by the local oil company geologists. From this log data, we derived rock physics relations for V_s versus V_p and also for P wave and S wave velocity and impedance versus porosity and bulk density. These relations can be used in seismic forward modeling and interpretation.

Data Analysis

Well A

The well log curves available in Well A are shown in Figure 1. This figure shows only the bottom interval with marl. Pay intervals are higher and not shown. The marl interval has relatively low GR count, practically constant S -wave (~ 2 km/s) and P -wave (~ 3.8 km/s) velocity, and practically constant Poisson's ratio (~ 0.31) which gives a constant V_p/V_s ratio of about 1.91.

The velocity and impedance versus density and velocity and impedance versus porosity cross-plots with the marl interval highlighted are given in Figure 2 and 3, respectively. Trends in these cross-plots are evident, especially in the impedance-density and impedance-porosity plots. The impedance trends fitted by straight lines are:

$$I_p = -4.7 + 5.78 RHOB,$$

$$I_p = 10.6 - 9.25 Phi,$$

where porosity is in fraction (p.u.), density is in g/cm^3 , and impedance is in $km/s \cdot g/cm^3$.

Poisson's ratio is plotted versus density and porosity in Figure 3. It is cross-plotted versus the P -wave impedance in the same figure. There are no trends present in these cross-plots for the marl interval simply because Poisson's ratio is essentially constant (between 0.3 and 0.32). This Poisson's ratio value can be probably used for V_s prediction and forward seismic modeling.

Well B

Well-log curves in Well B (Figure 4) have the same character as in Well A. However, the bottom interval in this well has much lower GR count and is much faster than the marl interval in Well B. The reason may be smaller amounts of clay and larger calcite or dolomite presence in Well B. It remains a question of definition, whether the very fast bottom interval in Well B is marl or not. Nevertheless, we include these data in our analysis. Notice also that Poisson's ratio in the (questionably) marl interval in Well B is about 0.31, about the same as in the marl in Well A.

In Figure 5 we plot the P -wave impedance versus the bulk density and porosity for both wells. The trends are different from those in the "soft" marl present in Well A. The linear fits are:

$$I_p = -30.4 + 16.558 RHOB,$$

$$I_p = 13.6 - 25.23 Phi.$$

Poisson's ratio is plotted versus the P -wave impedance for both wells in Figure 6. Although the impedance values differ between the two wells, Poisson's ratio remains practically constant, about 0.31.

Conclusions

Poisson's ratio in the marl intervals is constant and about 0.31 which corresponds to V_p/V_s ratio 1.91.

Rock Physics of Marls

In Figure 7, V_s is plotted versus V_p for the marl intervals together with empirical relations by Castagna et al. (1993) and Williams (1990). Notice that the marl data in Well A fall precisely on the empirical limestone curves close to their intersection with the mudrock (shale) curve and precisely at the intersection with the Williams shale line. The Well B data are on the limestone curves but farther from the mudrock line which confirms our

hypothesis that the Well B marl interval is predominantly limestone.

References

Mavko et al., 1998, *The Rock Physics Handbook*, Cambridge University Press.

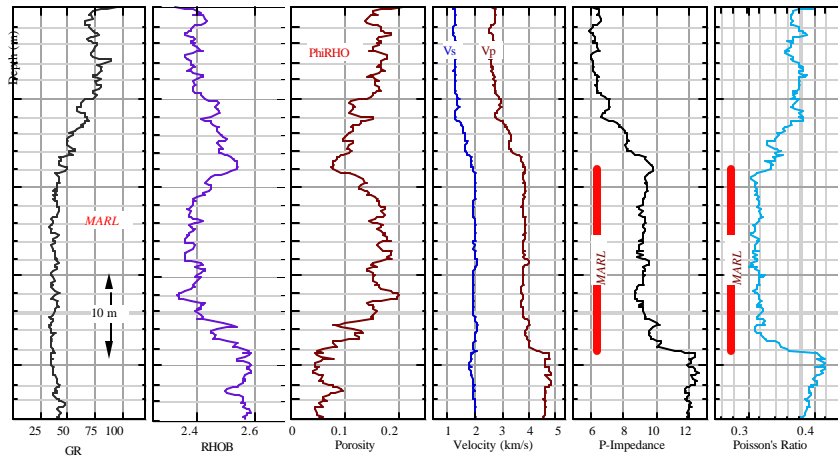


Figure 1. Well log curves for the marl interval in Well A.

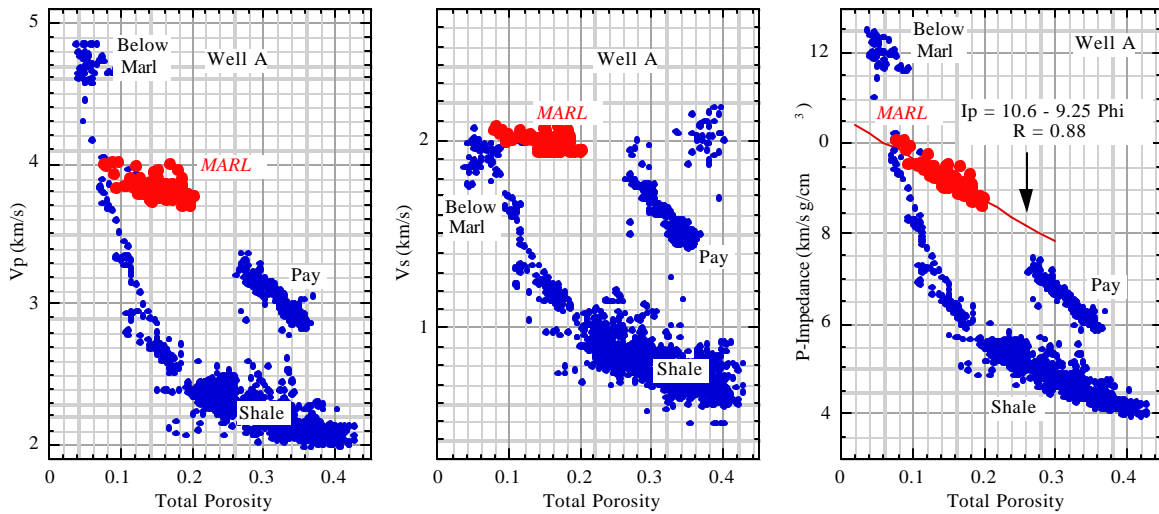


Figure 2. Velocity and impedance versus porosity in Well A.

Rock Physics of Marls

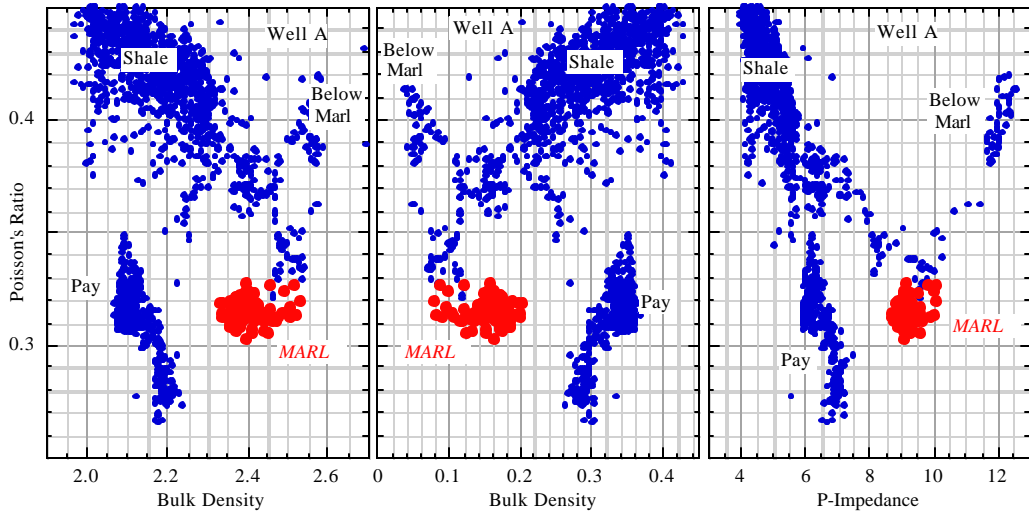


Figure 3. Poisson's ratio versus density, porosity, and P-impedance in Well A.

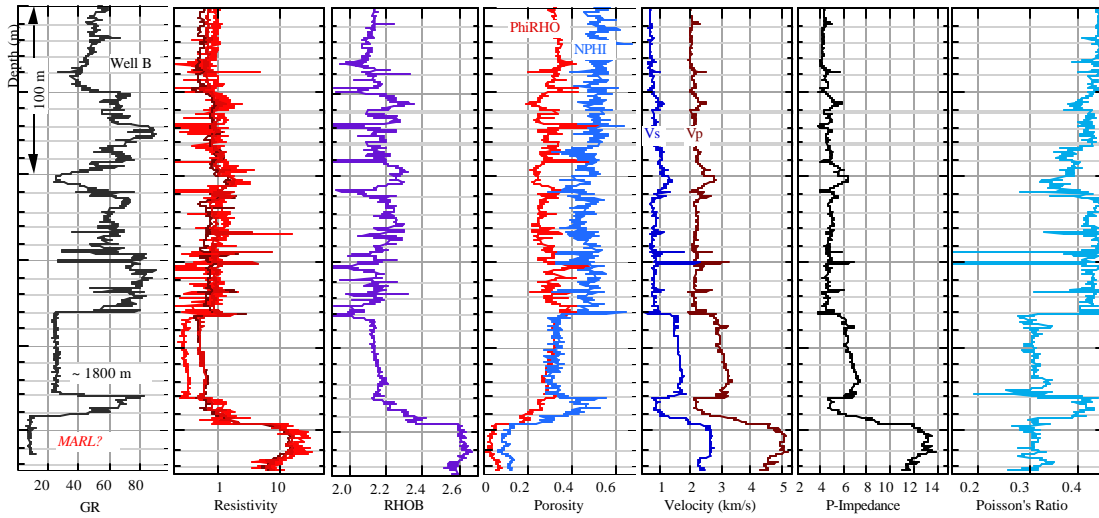


Figure 4. Well log curves in Well B.

Rock Physics of Marls

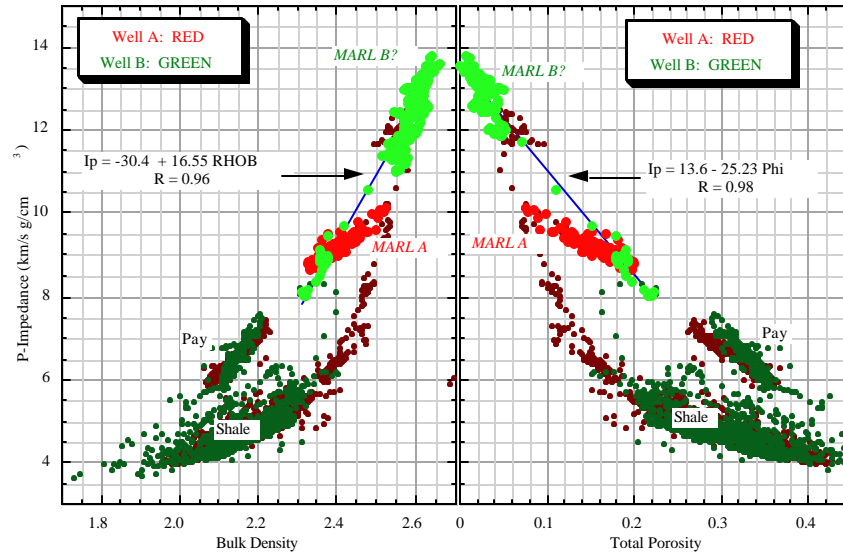


Figure 5. Cross-plots for Well A and Well B with marl intervals (questionable for Well B) highlighted.

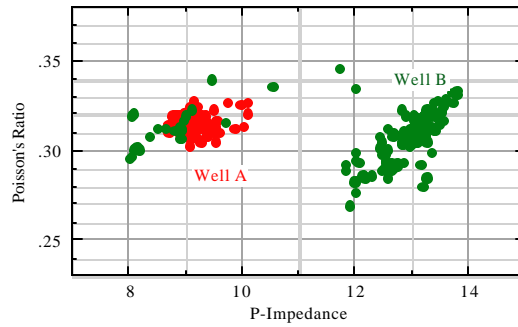


Figure 6. Poisson's ratio versus the P-wave impedance for marl intervals in Well A and Well B.

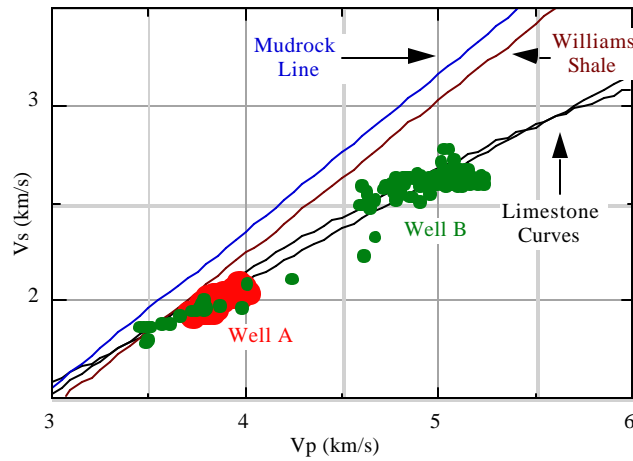


Figure 7. Vs versus Vp in marl intervals in Wells A and B plus existing empirical relations.