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Extended Abstract

Contribution of porosity and clay content on shear wave velocity in shaly rocks

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Abstract

Compressional and shear wave velocities (V_p and V_s respectively) are basic and essential parameters for any geomechanical modelling in deep ground conditions. However, both are complex parameters that are strongly influenced by other rock properties such as porosity, in situ stress, pore-filling, clay content, etc. Therefore, detailed information about the contribution of each of these attributes can improve the results obtained in geomechanical models. Especially when the wave velocity in the surface conditions is estimated based on in situ data such as geophysical logs from wells or core samples or drilling chips, the importance of this matter becomes much significant.

In this research, experimental data for more than 180 shaly rock samples were analysed. Clearly, porosity was the most critical parameter affecting shear wave velocity. Accordingly, increasing porosity leads to a dramatic decrease in wave velocity. Nevertheless, it was noticed that for a certain porosity value, a relatively wide range of wave velocities may be observed. Further investigation revealed that, clay content was also a significant contributing parameter. Based on explicit statistical analysis, a predictive equation was introduced with which shear wave velocity can be estimated with high certainty. Accordingly, for samples with the same porosity, variation in clay content would result in different wave velocities.

1. Introduction

Even though engineering geological aspects of shale were studied for several decades, there is still a serious lack of understanding in the context of petroleum, mining, and civil engineering projects. It is more interestingly to note that with the recent development of unconventional oil and gas resources in shale, the use of geomechanics principles has become even more important [1]. In case of petroleum geomechanical analysis and other deep subsurface projects, access to rock core specimens is very often limited or impossible [2]. Therefore, P and S wave velocities are the most important properties used for estimation of geomechanical parameters of rock formations, including Young's modulus (E), Poisson's ratio (ν), Uniaxial compressive strength (UCS), cohesive strength (c) and angle of internal friction (φ). However, compressional and shear wave velocities (V_p and V_s respectively) are affected by many other rock properties [3, 4] and ground conditions. Thus, a good knowledge about the parameters affecting wave velocity [5] is especially important when in situ measurements are used to back-analysis surface conditions (i.e. estimating Vp at the surface from in situ data), which, however, is currently very often ignored. Porosity, confining pressure (in situ stresses), pore-fill (substitution), wave frequency, and size effect (sample size) are among the most important parameters which influence wave velocity and other geomechenical parameters.

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2. Methodology

Extensive analysis on the data set showed that porosity is a very effective and necessary parameter for predicting wave speed. However, it was realized that for a given porosity value, a relatively wide range of velocities may be observed. Meanwhile, Shiyu and White (6) reported the effect of sand and clay porosity on wave speed by conducting different experiments. Based on these observations, it was assumed that in addition to porosity, clay content is another key parameter affecting shear wave velocity in shaly rocks, so that the effect of 3% clay is similar to the effect of 1% porosity. Fig 1 illustrates distribution of shear wave velocity data as such. Based on the regression analysis, equation (1) was the best fit for these data:

$$V_{s\ estimated} = 3.6 - 6(\phi + c/3) \qquad (1)$$

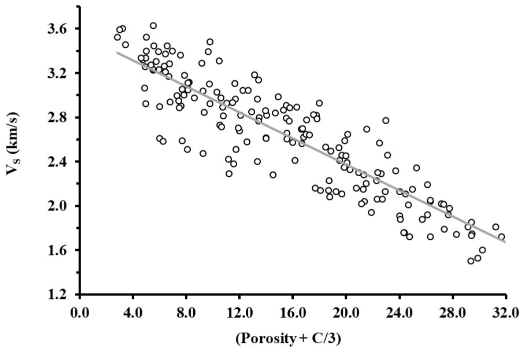

Fig. 1. Shear wave velocity (Vs) as a function of porosity plus one third of clay content in rock samples

3. Results and Conclusions

The analysis of laboratory data revealed that with increasing porosity, the wave speed decreases dramatically. An equation was proposed to predict shear wave velocity as a function of both porosity and clay content components. For further analysis, the measured data were plotted against the predicted values on a graph with a 45-degree symmetry line (y=x) as shown in Figure 2. As can be seen, the data have a symmetrical and balanced distribution around the symmetry line. This drawing shows that the predictive model equation confirms the desired hypothesis.

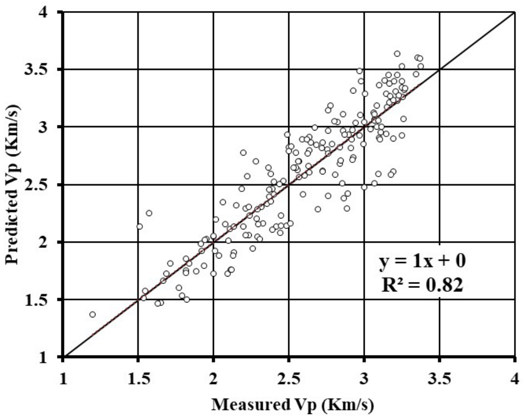

Fig. 2. Measured data (x axis) compared to the predicted values (y axis) based on equation (1) with respect to a 45 degrees symmetry line

4. References

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