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Modeling of S wave, P Wave velocity and petrographic properties: *Case study on sandstones in Pestehleigh Formation in Kopet Dagh basin*

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ABSTRACT

Extensive superficial expansion of sandstone formations can be seen in the north-eastern part of the Kopet Dagh Basin. Pestehleigh Formation is one of the sandstone formations of Kopet Dagh basin. In this study, 8 sandstone samples were taken from the Pestehleigh Formation and the shear (S wave) and compression (P wave) wave's velocity and petrographic characteristics of these samples were investigated. The results of this study showed that S wave and P wave velocities are more affected by porosity, silica, and calcareous cement. Moreover, it is shown that the effect of porosity on P wave velocity is 4 times more of the same effect in shear wave velocity, while the same effect of silica and calcareous cement is almost equal on each of these wave velocity. Finally, a suitable matrices model was introduced for estimating S and P wave's velocity utilizing these variables.

Key words: *P wave, S wave, petrographic properties*

1. *INTRODUCTION*

Extensive superficial expansion of sandstone formations is seen in the north-eastern part of the Kopet Dagh Basin. Due to the wide range of these structures, it is possible to implement engineering projects such as dam, tunnel, road and oil and gas well on these structures. In this study, the relationships between the characteristics of petrography including the type of cement and quartz, feldspar with S and P Waves on 8 samples of sandstone gathered from Kopet dagh basin.

The results showed that there is a significant linear relationship between the studied petrographic properties with the P and S waves. These results represent that the role of cement type in the sandstones on the values of the waves of this type of rocks is much more than the role of the rest of the petrographic features. To this end, the R^2 and adjusted R2 criteria have been used. According to these results, it is immediately understood that the role of cement type (silica or calcium) on the values of waves of these types of stones is more than the role of mineral types and porosity. Based on these outcomes, a relation with R2 at level 93 percent has been constructed for the estimating of P and S waves loads of sandstone-based on these type of cements. Ultrasonic waves also provide good information on subsurface geological characteristics and the information which are needed for drilling with various targets. Kinds of ultrasonic waves that include P and S waves. Get access to correlation, indirectly, is a suitable method for estimating mechanical properties but in some cases, it is reduced the need for more testing (Lashkaripour, 2002). There is a good correlation between compressive velocity, porosity, and density (Rahmouni et al., 2013).

2-Research Strategy

At first, during the field operation, eight sand samples from the Pestehleigh Formation in the Kopet Dagh basin in the northeast of Iran were taken (Figure 1). After transferring the sample blocks to the laboratory, they were incrusted with a 54mm diameter coring device with a length of diameter ratio in 2 to 2.5 and appropriate specimens were prepared according to ASTM and ISRM standards. Experiments of the P wave and S wave velocity were performed according to the

ASTM D2845 standard device. Then, the correlation relations between these parameters were investigated. Also, thin sections were prepared to determine the characteristics of rock exploration. Finally, the designation of sandstones was combined and five-point based on the Folk classification (1980) was placed on the diagram (Figure 2). Thin section analysis showed that sand castings of Pestehleigh Formation were classified according to the Folk classification (1980) in the quartz-Arnite, Sub-Arkoze and Arkuze categories.

Figure 1. Sample collection site. The coordinates of the sampling site of Mashhad-Dargaz road

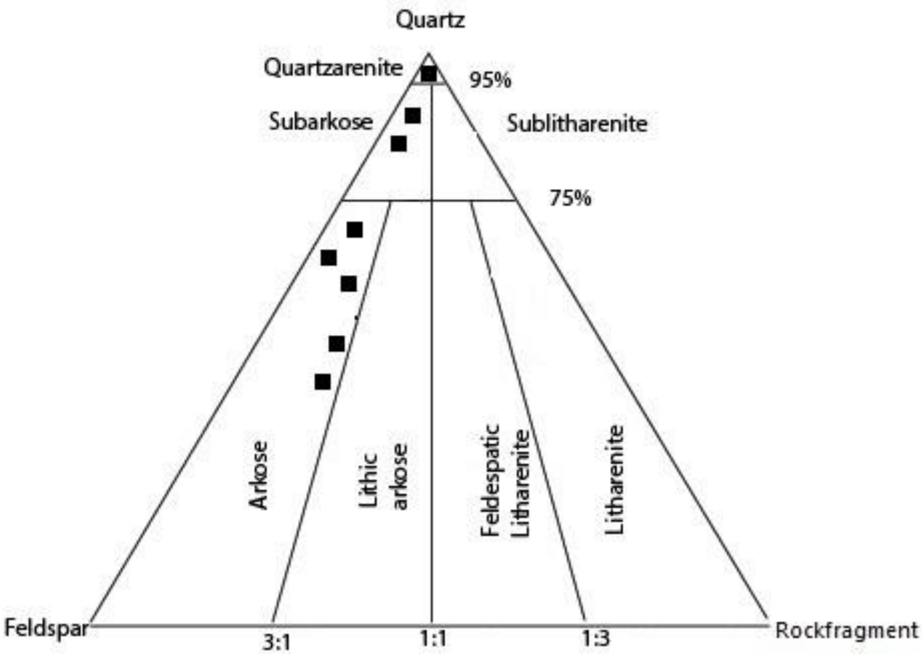

Figure2.The diagram of the sandstone of Pestehleigh formation classification based on (Folk, 1980) in this research

3-Statistical Modeling Procedures

In this section we are going to investigate the effect of quartz, feldspar, rock-fragment, porosity, and cement on the S wave and P wave velocity throughout some statistical modeling methods utilizing statistical software R.

Figure3. The effect of quartz, feldspar, rock-fragment, porosity, and cement on S wave velocity

S wave: Linear model without intercept	Porosity	Quartz	Feldspar	Rock fragment	Silica cement	Calcareous cement
R2	0.9067	0.0157	0.1132	0.0152	0.1853	0.0477
Adjusted R2	0.8911	-0.1483	-0.0345	-0.1489	0.0496	-0.1109

Due to this fact that the R2 criterion is positively corrected in porosity and silica cement variables, it is concluded that the relationship must be constructed between these variables and shear wave. On the other hand, considering the logical relationship between silica and calcareous cement, the relationship between these three variables with a shear wave has been investigated.

Derived empirical model for calculating shear wave on this study is as follows:

$$\text{S wave} = (0.0141\times\text{Porosity}) + (0.2135\times\text{Silica Cement}) + (0.0411\times\text{Calsitic Cement})$$

$$R^2=91.35;\ \text{Adjusted } R^2=86.16$$

According to the proposed model, it is obvious that the effect of porosity, silica and limestone cement on the shear wave is proportional to 1, 20 and 4, respectively. As a result, the greatest effect is on silica cement, which means that a unit increase in this variable causes the 0.20 unit increase in the shear wave while a same unit increasing porosity causes only 0.01 increasing in the shear wave as an independent variable in this model.

Figure4. The effect of quartz, feldspar, rock-fragment, porosity, and cement on P wave velocity

P wave; Linear model without intercept	Porosity	Quartz	Feldspar	Rock fragment	Silica cement	Calcareous cement
R2	0.8917	0.0117	0.1130	0.0166	0.1910	0.0417
Adjusted R2	0.8736	-0.1530	-0.0348	-0.1472	0.0496	-0.1179

Due to this fact that the R2 criterion is positively corrected in porosity and silica cement variables, it is concluded that the relationship must be constructed between these variables and P wave. On the other hand, considering the logical relationship between silica and calcareous cement, the relationship between these three variables with a P wave has been investigated.

Derived empirical model for calculating P wave on this study is as follows:

$$\text{P wave} = (0.0475\times\text{Porosity}) + (0.2947\times\text{Silica Cement}) + (0.0550\times\text{Calsitic Cement})$$

$$R^2=93.58;\ \text{Adjusted } R^2=89.73$$

According to the proposed model, it is obvious that the effect of porosity, silica and limestone cement on the P wave is proportional to 4, 29 and 5, respectively. As a result, the greatest effect is on silica cement, which means that a unit increase in this variable causes the 0.29 unit increase in the compressive wave while a same unit increasing porosity causes only 0.04 increasing in the P wave as an independent variable in this model.

As a comparison of this model and considering the similarity of dependent variables, it can be concluded that porosity has a greater effect (the effect is approximately 4 times more) on the compression wave compared to the shear wave. While the ratio of the effect of silica and calcareous cement on the two waves is relatively similar, they also affect the P wave a little more.

By combining the two models, and considering that in both models of the three related dependent variables, the relationship between these variables can be reviewed in the following matrices.

$$\begin{bmatrix} 0.0141 & 0.2135 & 0.0411 \\ 0.0475 & 0.2947 & 0.0550 \end{bmatrix} \times \begin{bmatrix} \text{Porosity} \\ \text{Silica Cement} \\ \text{Calsitic Cement} \end{bmatrix} = \begin{bmatrix} \text{S Wave} \\ \text{P Wave} \end{bmatrix}$$

It is obviously seen that according to the final model, with three dependent porosity, silica cement, and calcareous cement, both independent variables S wave and P wave can be predicted.

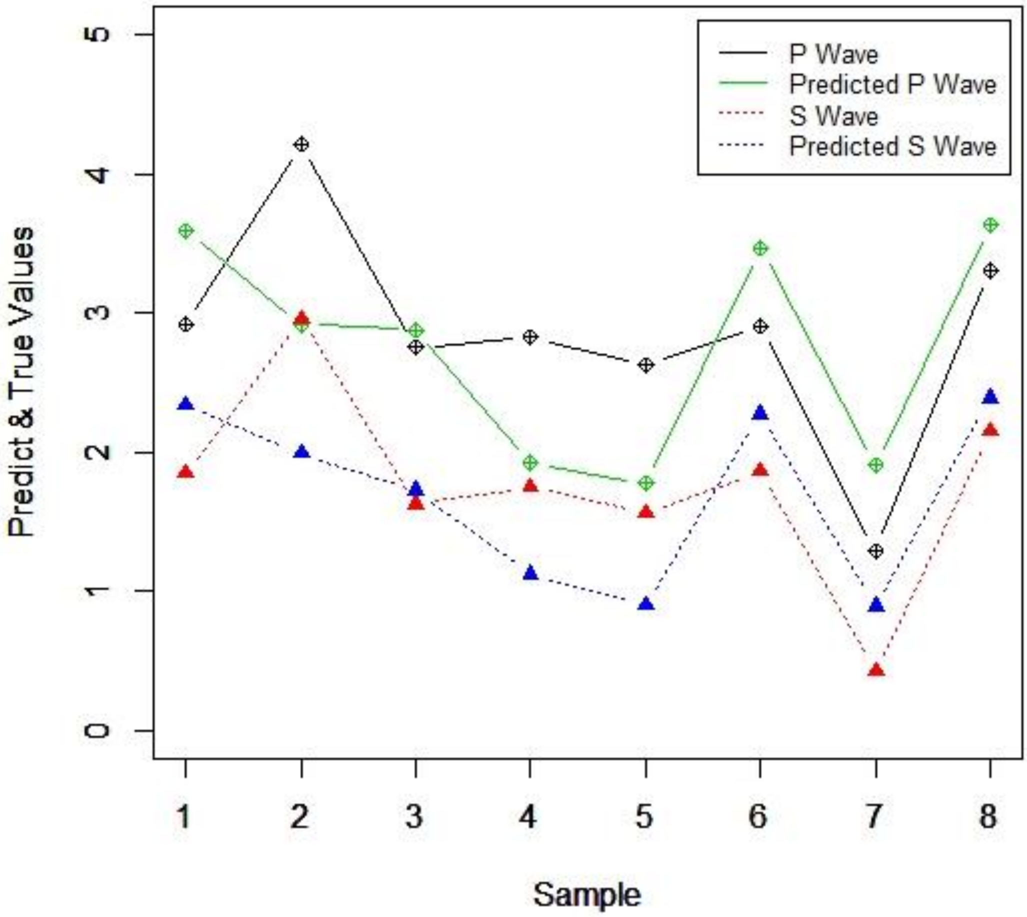

Figure5.Comparison of True and Predicted Values in Two Presented Regression Models

4-Conclusions

After carrying out the experiments on 8 samples of sandstone taken from the Kopet Dagh basin, the statistical analyzes obtained from them using the statistical software R showed that:

There was a significant linear relationship without intercept between shear wave with porosity, silica cement, and calcareous cement.

There was a significant linear relationship without intercept between condensation wave with porosity, silica cement, and calcareous cement.

The empirical matrices models have been proposed to predict P wave and S wave using porosity, silica cement, and calcareous cement.

The results show that there is a relation between the sandstone of Pestehleigh formation between petrographic properties with S wave and P wave, and the type of cementation plays a key role in the S wave and the values of these types of rocks

5-References

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