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Application of Artificial Neural Networks in Prediction of Uniaxial Compressive Strength of Rocks Using Well Logs and Drilling Data

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Abstract

It is critical to obtain the rock strength along the wellbore to control drilling problems such as pipe sticking, tight hole, collapse and sand production. The purpose of this research is to predict the uniaxial compressive strength based on data of sonic travel time, formation porosity, density and penetration rate. For prediction of UCS, artificial neural networks were developed between UCS and input data resulting a practical correlation. In this research, a long well segment possessing complete and continuous data coverage has been analysed, and collected data of the wellbore are used to correlate data of the four mentioned input parameters of artificial neural networks with uniaxial compressive strength data as network targets. Selection of input parameters is based on a vast literature review in this area. Due to the fact that standard experimental test methods based on established standards require costly equipment and that the methods for sample preparation is difficult and time-consuming, indirect methods are more favourable. Using these methods, the UCS values are predicted in a simpler, faster and more economical way. In this study, it is concluded that artificial neural networks are a good predictor of rock strength, and can reduce drilling costs significantly. It is observed in this paper that UCS predicted values by neural networks are very close with lab and field data, which is concluded by analysis of network performance results including mean squared error and correlation coefficient. It is also concluded in this study that input parameters which are chosen in this study, have deep effects in UCS prediction studies, and should be considered in other scientific studies. Conclusions show that using artificial neural networks to predict UCS of formation rocks in petroleum fields around the world, would ease UCS estimation, optimize drilling plans and decrease costs.

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Keywords: Uniaxial Compressive Strength; Artificial Neural Networks; Wellbore Drilling

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1. Introduction

A geomechanical model requires a great deal of input information including measurements of magnitude of vertical and minimum stresses, pore pressure, rock mechanics properties and drilling experiences, all oriented to determine the magnitude of maximum horizontal stress. To conduct a geomechanical reservoir characterization, it is essential to have the knowledge of the in-situ stress magnitudes and rock mechanical properties [17].

Uniaxial compression test (unconfined compression test) is one of the most important tests used to measure rock strength. It is critical to obtain the rock strength parameters along the wellbore. Rock strength controls the drilling rate of penetration (ROP) [1]. Knowledge of the in situ mechanical profiles of the reservoir interval is critical in planning horizontal well trajectories and landing zones, placement of perforation clusters along the lateral, and optimal hydraulic fracture simulation design. However, coring, logging and core analyses are expensive and time consuming. In addition, as they are typically performed in a few wells that are assumed to be representative, there is considerable uncertainty in extrapolating results across wide areas with known variability in stratigraphy, faults, thicknesses, hydrocarbon saturations, etc. [2]. Thus, an integrated rock mechanical study can be considered an investment in field development. In practice, however, many geomechanical problems in reservoirs must be addressed when core samples are unavailable for laboratory testing. In fact core samples of overburden formations are almost never available for testing [6]. Rock mechanical laboratory testing on core samples are the most accurate methods for estimation of rock strength, but they never can lead to a continuous profile of rock strength along wellbore. Coring is very expensive and results are very sensitive to stress unloading [3].

Indirect methods are relatively simple and generally do not require any sample preparation. Due to the fact that standard experimental test methods based on established standards require costly equipment and that the methods for sample preparation is difficult and time-consuming, indirect methods are more favourable [1]. The use of such relations is often the only way to estimate the strength of rocks due to the absence of cores for laboratory tests. The basis for these relations is that many of the same factors that affect the rock strength, also affect other properties such as porosity. On the other hand, due to changes in the rock composition and properties, none of the correlations could be applied as an exact universal one. In such conditions, the proposed artificial intelligence method could be an appropriate candidate for estimation of the strength parameters.

This paper reports a method for estimation of mechanical rock properties in every well in a development. The purpose of this research was to predict the uniaxial compressive strength as a function of sonic travel time, penetration rate, density and formation porosity. In this work, a large well segment in Iran has been analysed which there is no information break throughout the segment and it is investigated continuously. To accomplish the objectives of this study, the drilling data from offset wells have been utilized to calculate the rock strength along the wellbore. Field data sets are used in this research to predict UCS based on the data of four input parameters chosen in the study.

Nomenclature

E	Young's modulus
ROP	Rate of penetration
UCS	Uniaxial compressive strength
ρ	Bulk density
φ	Formation porosity
Δt	Sonic travel time
MPa	Mega-pascal
m/s	Meter per second
psi	Pound per squared-inch
V_p	P-wave velocity
µs/ft	Micro-second per foot