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Inverse reservoir property estimation and artificial neural network-assisted 3D modeling of the Montney Formation, Alberta

Sochi C. Iwuoha / Behrad Rashidi / Per K. Pedersen / Christopher R. Clarkson

Geoscience Department, University of Calgary

Abstract

Three-dimensional (3D) reservoir characterization studies require many inputs, including well log data. However, in most multi-fractured horizontal wells (MFHWs) a conventional suite of well logs is not aquired in the lateral section. Researchers have previously shown that unconfined compressive strength (UCS) can be calculated from drilling rate of penetration (ROP) data. We extend the utility of this drilling-derived UCS by utilising regression analysis to obtain a correlation between drilling-derived UCS and dynamic UCS calculated from well logs. Vertical wells completed in the Montney Formation, Alberta, are used as reference wells for this purpose. By applying empirical relationships developed by prior researchers, we have back-calculated dynamic Young's modulus (E), Poisson's ratio (σ), compressional velocity (Vp) and porosity (ϕ) for the reference vertical wells and have demonstrated that the back-calculated logs are well-correlated with UCS, E, σ, Vp and ϕ computed from well logs in the reference wells. Comparison with core and seismic-derived properties are further performed.

Building on these established relationships, we have applied our workflow to compute UCS, E, σ, Vp, ϕ, permeability (K), and other elastic moduli (Bulk and Shear modulus) in Montney MFHWs for which well logs were not acquired. To demonstrate the relevance of this study, we have generated and compared two 3D ϕ and K models of the Montney Formation over our study area: one constructed using the back-calculated properties, and the other with well log-interpreted ϕ and K. We have extended our evaluation to gain a first order perspective on the distribution of secondary porosity in our study area. To achieve this, we have developed, and will present, an artificial neural network (ANN) model that predicts secondary (most likely natural fracture) porosity using UCS, E and σ. A 3D secondary porosity model has been built as a high-level input for natural fracture modeling and an evaluation of diagenetic contribution to secondary porosity development.

The methodologies presented in this work extend the current approach of 3D geological modeling in the Montney. These methodologies can be applied in the absence of downhole logs and core data, although these are required for model calibration. The more detailed perspective of the 3D distribution of matrix properties and potential secondary porosity development presented in this research may yet hold the key to advancing our understanding of challenging issues such as static fluid phase distribution in the Montney Formation.

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