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Methods for Upscaling Diverse Rock Permeability Data for Reservoir Characterization and Modeling

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Abstract

The primary sources of rock permeability data are cores and logs. Core-based permeability data are sampled from the reservoir at different scale from log-based permeability data. Consequently, porosity-permeability cross-plots from core plugs and logs are sensitive to the methods used in averaging the permeability data. For instance, arithmetic averaged core permeability data translated to log scale can be an order of magnitude greater than the core plug data at a given porosity. Using Dykstra-Parsons coefficient as a measure of reservoir heterogeneity, arithmetic averaging of permeability data is not suitable as the rock becomes more heterogeneous. Other methods such as geometric or harmonic averaging may be more appropriate.

Core heterogeneity below the vertical resolution of log NMR measurements has an impact on the methods used to calibrate NMR permeability data using core data. A method presented in this paper compares core permeability data with the NMR permeability data to account for sample volume differences utilizing high-density mini permeameter or high-density RCAL permeability data with different averaging techniques to simulate the vertical resolution of the NMR log.

This paper demonstrates the impact of averaging methods on upscaling permeability from core to log scale. Several unique methods for scaling up permeability data of heterogeneous rocks for reservoir characterization are recommended. These methods will generate more realistic characterization of reservoir models in terms of distributions of permeability property in the models.

The paper compared kh (permeability-thickness product) calculated from mini-DST tests to those calculated from core and profile (mini-permeameter) permeability data. The results of the comparisons are inconclusive. The kh from the mini-DST tests are not correlateable to those calculated from profile permeability data. The differences in kh values are traceable to uncertainty associated with depth shifts and the difficult task of ensuring that we are actually comparing data from the same depths or formation intervals.

Introduction

Rock permeability is a measure of its ability to transmit fluids. For most reservoirs, permeability data are direct indicators of performance in terms of oil recovery and well productivity assuming there are no other adverse geologic features and/or poor fluid properties present. However, unlike other basic rock properties such as porosity and fluid saturations, there are no tools available at present in the industry for direct, continuous measurement of permeability in the reservoir. The commonest tool currently available in the industry for in-direct measurement of permeability in the reservoir is the Nuclear Magnetic Resonance (NMR) tool. Permeability data calculated from the log response of the NMR tool depend on porosity data from porosity logs (such as Density, Neutron, NMR and Sonic logs) and regression analyses with correlational equations such as the Timur-Coates[1] equation for interpretation. Hence, NMR permeability data must be calibrated with permeability data from other sources such as cores before they can be applied.

Permeability data from cores are usually sampled at a different scale from permeability data from NMR logs. The difference in scale must be reconciled before using core based permeability data to calibrate NMR based permeability data. The process of reconciliation of these two sources of permeability data may involve application of various averaging schemes in order to bring the core scale in conformity with the log scale. In this paper, we present various averaging techniques and the influence they could have on the resulting permeability data. We also provide recommendations on the best practice for averaging of permeability data and their applications for reservoir characterization.

Averaging Techniques for NMR Permeability Data

We begin by using a simplified synthetic sand-silt model to illustrate the impact of averaging techniques on permeability data. The synthetic model is made up of ten layers of equal thickness composed of various ratios of two sands which we call Sand A and Sand B (Figure 1). The properties of Sand A and Sand B are summarized in Table 1.