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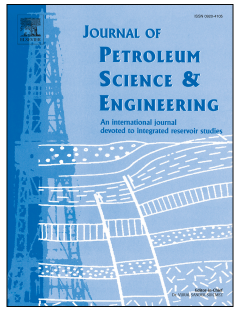

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A Modified Model to Describe Porosity-Temperature Relationship

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Abstract

This work presents some of the main contributions in the discussion about porosity changes due temperature and an analytical model to describe them when temperature variations occur. The model is based on two mechanical theories: poroelasticity, which considers three different volumes (bulk, solid frame, and porous) in their answers to stress change, and thermoelasticity that allows calculating the mechanical stresses related to temperature changes using thermal expansion. To achieve a more realistic behavior, a previous model is modified by adding the action of confining pressure as a new variable and multiple modifications of the thermal expansion coefficients from laboratory evidence. Those modifications allow the overcoming of either over or underestimation problems.

In the proposed model, three modifications are applied to achieve a better approach of actual phenomena: 1) The thermal expansion coefficient is understood as non-linear, 2) the expansion of bulk and constitutive material are differentiated, and 3) the bulk volume is dominated by a new concept of modulated strain that combines thermal and confining stress, in order to include confining stress into the model.

It is found that porosity changes happen as a result of the interaction between the thermal and confining stresses. Therefore, the model describes two phases. In the first phase, porosity decreases as a consequence of the constant bulk volume while the solid volume expands, thus accumulating thermal stress. In the second phase, the thermal stress overcomes the confining stress, triggering a porosity recovery.

Some applications, such as permeability calculation using Carman-Kozeny correlations are presented. These calculations may give an idea on how the temperature could change the formation's petrophysical properties. Furthermore, a simple formulation of a safe injection temperature can be derived from the concept of maximum allowed reservoir deformation, which depends on temperature change and overburden pressure.

Finally, the sensitivities of the new model are presented in order to analyze the impact of mechanical and thermal properties within the porosity calculations.

Keywords: Thermoelasticity, poroelasticity, porosity change, permeability change, temperature effect, confining stress, caprock integrity.

1 Introduction

Heavy oil, extra heavy oil, and bitumen deposits on sandstones represent a huge resource in the global energy market due to their large reserves throughout the world. Shafiei and Dusseault (2013) mention an estimate of approximately 7.3 trillion barrels [TB] with significant oil reserves in Venezuela, Russia, and

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