SPE 115429

Advanced Compositional Gradient Analysis

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This paper was prepared for presentation at the 2008 SPE Annual Technical Conference and Exhibition held in Denver, Colorado, USA, 21–24 September 2008.

Abstract

Steep gradients are common in gas condensate and volatile oil reservoirs, but they are also present in heavy oils reservoirs. There are numerous publications (Creek, 1985, Lars Høier, 2000, Montel, 2002, Firoozabadi, 1999, Ghorayeb, 2003, Fujisawa, 2004, Elshahawi, 2005, and Kabir, 2006) that have dealt with complex fluid columns showing compositional gradients for columns in thermodynamic equilibrium or under steady state conditions. Montel et al. (2002) discuss processes that arise from recent charging of these reservoirs, which are not in equilibrium but still undergoing for instance a flux of the light components that diffuse.

Formation testers supply a wealth of information to observe and predict the state of fluids in petroleum reservoirs, through detailed pressure and fluid analysis measurements. With the correct understanding of fluid characteristics in the reservoir, reserve calculations and adequate development plans can be prepared. Additionally, flow barriers may then be revealed, as across such barriers, fluid may appear different. In order to test for the existence of such barriers, pressure or fluid differences, in their context must be assessed. Formation tester data must therefore be treated by means of a systematic analysis, so that different sources of information lead to an integrated, preferably, consistent conclusion. Downhole fluid analysis in conjunction with pressure gradient analysis is simultaneously analyzed to reflect and make deductions concerning the correct state of fluids in complex fluid columns. As part of the process, different reservoirs need to be well delineated through appropriate statistical similarity tests of pressure gradients and fluid analysis of the different zones (Kabir, 2006).

In this paper, a novel methodology is presented to account for non-linearity in pressure gradients due to varying fluid density. We examine two field cases in which compositional gradients were observed with both downhole fluid analysis measurements and pressure gradients. An equation of state model is used to describe the fluid column according to a simple fluid equilibrium model. A non-linear pressure gradient regression fit is also examined. The choice and appropriateness of the pressure gradient model that accounts for the observed fluid density changes observed. The result of the modelled fluid and pressure analisis are compared to actual downhole measurements of the pressure profile and insitu fluid logs. In particular, pressures and densities calculated from the multiple sources of information, pressure and fluids, are compared to direct actual measurements. The reservoir architecture is revealed. For both cases, the fluid column is continuous through the hydrocarbon intervals down to the water-oil contacts. Flow barrier locations would be found on the basis of anomalies and departures of the measured data from the modelled pressure and fluid gradients.

Introduction

Compositional variations in reservoir fluids with depth are more common than perhaps normally expected and have been observed in several reservoirs throughout the world. This phenomenon is not limited to thick reservoirs, but is observed also over relatively short vertical columns. This is also not only limited to reservoirs containing gas condensates or volatile oils, but is observed in heavy oil reservoirs as well (Mullins et al, 2005, Mullins et al, 2007).

There are several different mechanisms that may create fluid compositional variations in reservoir fluid columns. Fluid gradients can originate from gravitation, thermal gradients, biodegradation, water washing, current reservoir charging, multiple reservoir charges, leaky seals, time and temperature dependent variation of hydrocarbon properties from kerogen catagenesis, variation in deposited kerogen and production schemes, such as compositionally differential production (e.g. production below a phase transition), or miscible flooding. Only the first two mechanisms drive the hydrocarbons towards