SPE 115028

Utilizing 4D Microgravity To Monitor Water Encroachment

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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.

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Abstract

The common wisdom is that gravity methods have limited application in the oil industry although they have long been available. The main use of gravity has been for exploration purposes. 4D microgravity monitoring is another new promising gravity application to monitor changes of fluid contacts. Some successful 4D monitoring surveys have been conducted in the industry revealing that this technique is a proven technology in monitoring of gas-water contacts.

This paper studies the ability of microgravity to capture movement of the injected water in a giant carbonate field. The oil-water case is more difficult due to the significantly lower density contrast as compared to the gas-water case. Monitoring water floodfront in the field is a key factor in applying successful reservoir management practices to maximize recovery and prolong the field life. The monitoring of inter-well fluids would characterize any pre-mature water breakthrough to allow planning and design of appropriate remedial well interventions. The current applied monitoring tools such as carbon-oxygen and resistivity logs can only detect fluids near to the wellbore due to their shallow radius of investigation. For the study field, 4D seismic cannot be used for fluid movement detection due to issues related to formation acoustics impedance and data quality.

The study has shown that surface microgravity monitoring could successfully detect the inter-well fluid changes due to water injection with a high precision tool (0.01 microgal). It also shows that microgravity monitoring can capture water bodies located hundreds of meters away from the location of the 4D measurement.

Introduction

The monitoring of inter-well fluids would characterize any pre-mature water breakthorough to allow planning and design of appropriate remedial well interventions. The conventional monitoring tools, such as NMR, carbon-oxygen and resistivity, can only detect the water flood front near to the individual wellbore due to their short radius of investigation[1]. The radius of investigation of NMR and carbon-oxygen tools is limited to few inches while the resistivity tools can detect up to few feet into the reservoir. The resistivity water saturation calculation is also dependent on several, often uncertain, petrophysical input parameters like m, n and Rw. If the salinity of the original formation water and the injected water differs, a mixed reservoir water salinity environment is generated, which can add a particular challenge in defining the Rw input as the salinity may change with depth in each individual producing well.

It is apparent that available shallow radius of investigation tools lack the needed reservoir coverage to map the reservoir enchroachment over time. Only after water is observed in the well can the location of the floodfront be mapped with any certainty. The techniques that provide adequate reservoir coverage, such as 4D seismic or cross-well resistivity, may not provide the required resolution and accuracy in saturation estimation. In the study field, 4D seismic cannot be used due to a weak 4D response. The small change of acoustic impedance from oil-bearing formation to water bearing formation is responsible for the weak 4D seismic effect complicated by surface statics. The new alternative techniques such as cross-well resistivity have some operational constraints pertinent to the well completion.

Gravity methods have simple equations and robust nature of measurement, which give them greater advantage over other methods such as seismic[2,3]. However, the non-uniqueness problems restricted gravity applications in the oil industry[4]. The main use of gravity is for exploration purposes when seismic surveys are not applicable, such as when a salt diaper is present[5]. In the latter situation, its objective is to assess in the processing, imaging and/or interpretation of seismic.

Time-lapse microgravity is a new evolving gravity method that is used to monitor fluid changes with time in the reservoir. The survey should have an array of surface measurements covering the study area with reasonable spacing between each measurement. Borehole microgravity measurements can also be used in the survey to aid in understanding the gravity signal.