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Comprehensive management of mineral scale deposition in carbonate oil fields – A case study

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ABSTRACT

The majority of oilfields, especially those under water injection suffer from scale deposition. The common method of addressing the scale issue is to deploy the integrated scale risk management, by which the data from all available disciplines such as Chemistry, Field Engineering, Completion Engineering, etc. are integrated to make the most suitable decision. The main aim of this study is to perform integrated scale risk management in the A carbonate oil field, under water injection.

Several experimental, field and simulation studies were done to investigate the main causes of scales. Produced waters were sampled and analyzed every three months to follow their compositional variations. Comprehensive atmospheric and core flood tests were carried out to assess the impact of deposited scales. Moreover, several real samples of scales were sampled and analyzed. Since the reservoir rock is carbonate type, the emphasis must be on the associated challenges such as rock–fluid interaction and fluid flow. Several simulators including finite difference, streamline, and reaction simulators (CMG_GEM GHG) were used to study the scales and the communication between wells.

Integrating the results, a comprehensive workflow was designed for the continuation of this study and analog fields. The main sources of scales, their types and severity through the reservoir were evaluated and reactive and proactive approaches were suggested to reduce or eliminate the scale risks. Furthermore, this study shows that a proper design of inhibitor placement by coil would result in satisfactory placement for all wells, and fluid–rock interaction raises the severity of Calcite deposition.

Keywords: Scale control; Scale management; Carbonate reservoirs; Scale simulation; Formation damage; Oil field scale

1. Introduction

The effective management of mineral scales during the lifetime of oilfield is vital if economical hydrocarbon production is to be maintained. Mineral scales are formed as a process of deposition from aqueous solution of minerals, referred to as brine, when they become supersaturated as a result of change in the state of their thermodynamic and chemical equilibrium, i.e. ionic composition, pH, pressure and temperature (Vetter et al., 1982; Jordan et al., 1994; Oddo and Tomson, 1994; Bertero et al., 1998; Civan, 2000; Mackay et al., 2004; Moghadasi et al., 2004).

There are three principal mechanisms by which scales form in oilfield operation (Mackay et al., 2004):

1) Decrease in pressure and/or increase in temperature of a brine, leading to a reduction in the solubility of salt (most commonly these lead to precipitation of carbonate scales, such as $CaCO_3$).

Abbreviations: ICP, inductively coupled plasma; SI, saturation index; PV, pore volume; XRD, X-ray diffraction; XRF, X-ray fluorescence; WAF, well allocation factor.

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2) Mixing of two incompatible brines (most commonly formation water rich in cations such as barium, calcium and/or strontium, with sulphate rich seawater, leading to the precipitation of sulphate scales, such as $BaSO_4$).
3) Brine evaporation, resulting in salt concentration increase above the solubility limit and leading to salt precipitation (as may occur in HP/HT gas wells where a dry gas stream may mix with a low flow rate brine stream resulting in dehydration and most commonly the precipitation of NaCl).

Scales can damage well productivity and/or injectivity in terms of permeability reduction, plugging production lines and equipment. The consequence could be overall decrease in production efficiency, production-equipment failure, emergency shutdown, and increased maintenance cost. The failure of these facilities could result in safety hazards, in addition to the above problems (Vetter and Phillips, 1970; Mackay, 2003a,b; Moghadasi et al., 2003; Stalker et al., 2003; Mackay and Jordan, 2005; Taheri et al., 2011).

Scales can also form deep within the reservoir. In other words, the reduction of scales forming ions will lessen the severity of scale deposition in vicinity of the production wells. The phenomenon of reservoir stripping has been reported as a favorable process in the context of scale management, since the deep deposition does not affect the flow of hydrocarbon, considering the large radius of the reservoir (Mackay et al., 2003, 2004; Jordan et al., 2003).

Table 1 shows the most common scales of the oilfield along with their primary influencing factors. The first step to resolve the scale formation problem is to have a holistic understanding of the scale formation process through the life of a reservoir. So far, the most effective methodology to address the scale problem is the integrated scale risk management, in which all the factors that impact the scale formation are investigated as to select the best technical and economical strategies.

Table 1 – Common oil field scales (Moghadasi et al., 2004).

Name	Chemical formula	Primary variables
Calcium carbonate	$CaCO_3$	Partial pressure of CO_2, temperature, total dissolved salts, pH
Calcium sulphate		
Gypsum	$CaSO_4 \cdot 2H_2O$	Temperature, total dissolved salts, pressure
Hcmihydratc	$CaSO_4 \cdot l/2H_2O$	
Anhydrite	$CaSO_4$	
Barium sulphate	$BaSO_4$	Temperature, pressure
Strontium sulphate	$SrSO_4$	Temperature, pressure, total dissolved salts
Iron compounds		
Ferrous carbonate	$FeCO_3$	
Ferrous sulphide	FeS	Corrosion, dissolved gases, pH
Ferrous hydroxide	$Fe(OH)_2$	
Ferrous hydroxide	$Fe(OH)_3$	

Scale risk management analysis basis and how to deploy as much as possible tools, including thermodynamic model, water evolution data, flow simulators, etc. have been reviewed thoroughly in previous papers (Sorbie and Mackay, 2000; Mackay et al., 2003, 2004; Jordan et al., 2003).

In case of carbonate rock, the scale risk becomes worse in terms of rock–fluid interaction and fluid flow. Therefore, these issues must be taken into account if the field is a carbonate type.

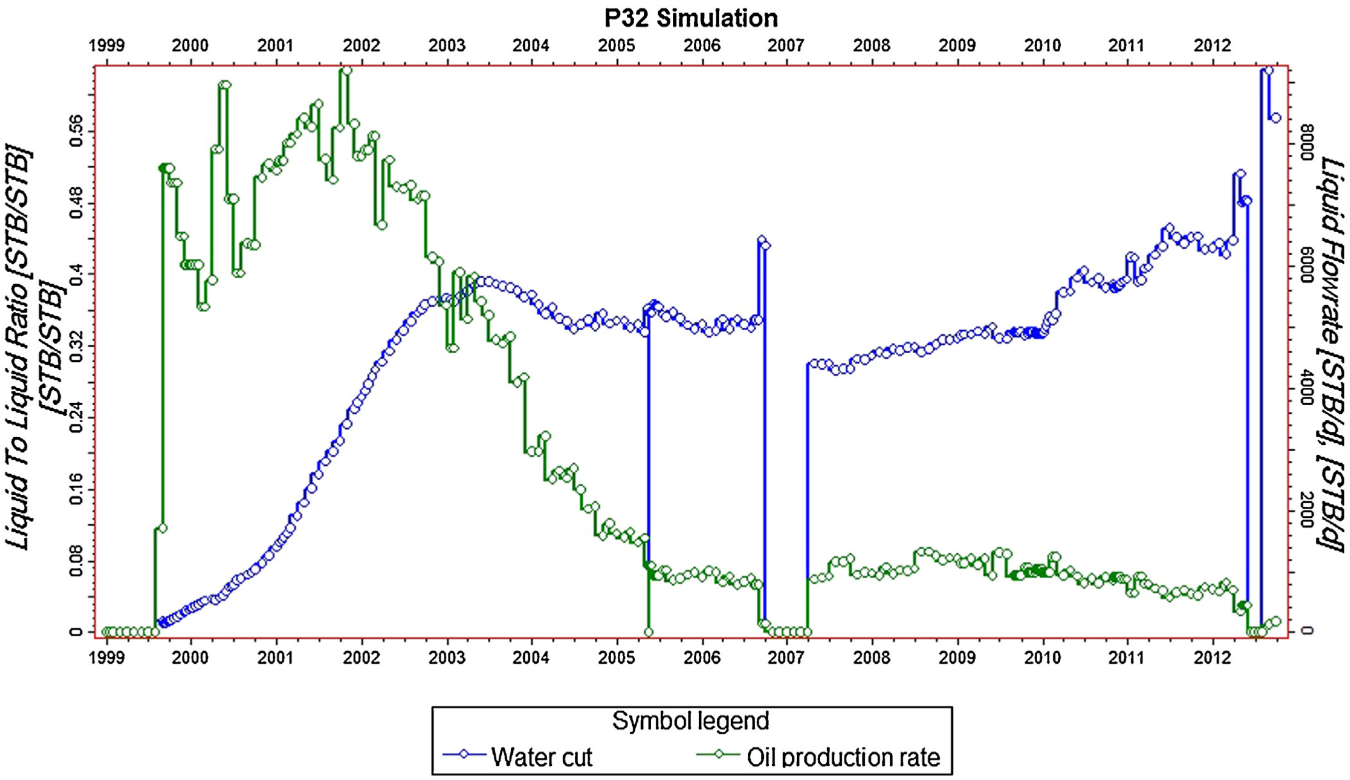

Fig. 1 – Increase in water cut and decrease in productivity in well P32-increase in water volume is usually associated with the problem of mineral scale deposition and consequently decrease in productivity.

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