



Mitigation of anhydrite dissolution in alkaline floods through injection of conditioned water

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HIGHLIGHTS

- ▶ We prove that EDTA does not decrease calcium concentration in anhydrite-containing rocks.
- ▶ A new paradigm to mitigate anhydrite dissolution during alkaline floods has been tested.
- ▶ Engineered water is a potentially effective strategy to produce ASP blends.

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ABSTRACT

Chemical enhanced oil recovery projects occasionally introduce an alkali agent to meet design requirements. The alkali agent reacts with reservoir rock components upon injection in reservoirs. It has been reported that the interaction of the injected alkali with some minerals in the rock assemblage, particularly anhydrite, is responsible for the very large alkali consumption, formation of secondary minerals, and regulates water chemistry. These effects, when unanticipated, can jeopardize the success of a chemical flooding project. In this study, single and two-phase flow flooding tests were carried out using rock samples from a sandstone reservoir in Wyoming to investigate the impact of multiphase flow on anhydrite dissolution at high-pH conditions. Effluent water chemistry was analyzed to investigate rock–fluid interactions taking place during an alkaline flood. Rock samples were CT-scanned to find out anhydrite distribution. Mitigation of harmful effects of rock–fluid interactions under alkaline flooding has been proposed through the addition of ethylenediaminetetraacetic acid (EDTA) to act as a calcium chelating agent. The effectiveness of EDTA was tested in single- and two-phase flow experiments. An alternative approach to mitigate damaging effects of alkali injection in anhydrite-containing rock, based on conditioning of injection water, was tested in this work. Results show that anhydrite dissolution diminishes when crude oil is present, but the effect depends on rock exposure time to oil (aging). In spite of the apparent decreased reactivity, anhydrite dissolution is still very pronounced in two-phase flow experiments. Results also show conclusively that water conditioning intended to diminish anhydrite dissolution chemical driving force is a more effective strategy to attain sustainable flooding conditions.

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1. Introduction

The importance of an alkali agent in chemical enhanced oil recovery methods has been studied vastly for more than four decades. It has been claimed that alkali enhances oil mobilization through three main mechanisms: first by lowering IFT due to generation of in situ soap [1–4], second, by lowering interfacial tension (IFT) between oil and water to ultra-low values in combination with surfactants [5–9] and third, by altering the wettability of the rock surface [10]. Moreover, an alkaline agent is able to

sequester divalent cations from the aqueous phase thus regulating the phase-behavior of the surfactant-soap system [11]. Also, by increasing the negative charge density on rock surfaces, an alkali agent reduces the adsorption of anionic surfactants and partially hydrolyzed polyacrylamide (HPAM) on rock surfaces [11–13], which can aid ASP flooding economic feasibility. The aforementioned roles of alkaline agents are attributed to their ability to increase pH. The propagation of a high pH front through a formation is a strong function of alkali consumption, as well as alkali type. In general, alkali consumption can be induced mainly by the following four reactions with: (1) crude oil (during the saponification process), (2) multivalent cations in the formation water, (3) clays through the cation exchange process and finally, and (4) minerals during the dissolution and precipitation processes.

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Table 1
Properties of the crude oil.

Property	Value
Specific gravity (48 °C)	0.92
Viscosity (48 °C) (cP)	83
Total acid number (mg KOH/gr oil)	0.43
SARA analysis	Asphaltenes: 5.41%
	Saturates: 35.29%
	Aromatics: 35.18%
	Resins: 8.85%
	Volatiles: 15.27%

Table 2
Properties of the cores.

Core	1-85b (two-phase flow test)	1-85b (single-phase flow test)	1-76	1-107	1-85 1
Length (cm)	7.53	7.53	7.59	7.87	7.65
Pore volume (cc)	10.74	10.84	14.81	14.38	13.13
Porosity (%)	12.71	12.85	17.4	16.2	15.3
Permeability _{air} (mD)	54.3	57.3	233.3	88	140.7

Among the aforementioned consumption mechanisms, those associated to crude oil represent a small fraction only [14] and it is mainly a function of the type and concentration of alkali agent and also the type and the amount of organic acids present in the crude oil. Generally, consumption of alkali by reactions with crude oil and formation water can be obtained or estimated in batch experiments or simple fluid–fluid interaction analysis, whereas, realistic analysis of alkali consumption by rock (including both clays and minerals) requires more complex dynamic tests and geo-

chemical simulations. In contrast with consumption of alkali by clays that is usually prompt and reversible, the consumption of alkali by minerals is irreversible and generally slow. However, anhydrite, with high dissolution kinetic rate, hastens the consumption rate of alkali significantly. The interaction of alkali with minerals, particularly anhydrite, leads to mineral dissolution and consequent scale formation resulting in possible porosity–permeability alteration and significant changes in water chemistry. Therefore, studies of anhydrite dissolution under various conditions is paramount to the success of chemical enhanced oil recovery methods.

In this study, single- and two-phase flow alkali flooding tests were carried out on core samples from a sandy reservoir in Wyoming to investigate the impact of oil on anhydrite dissolution at reservoir temperature. Single-phase flow experiments referred to aqueous phase flooding in the absence of any oleic phase, so that aqueous-phase saturation is always 100%. This type of experiments provides rock–water reactivity data at 100% water saturation. Two-phase flow experiments imply partial saturation of crude oil and aqueous phase. This classification does not imply that both phases always flow. For instance, when residual oil saturation is attained, only aqueous phase is produced, but we still refer to this as a two-phase flow experiment. It is a convenience rather than a precise terminology.

In order to address the intensity of rock–fluid interactions, effluent samples were analyzed to track water chemistry during the test. Cores were CT-scanned before and after flooding to examine the initial and final anhydrite distribution. We investigated claims on the potential of ethylenediaminetetraacetic acid (EDTA) as calcium sequestering agent through single and two-phase flow experiments in this anhydrite-containing rock. An alternative approach based on water conditioning proves to be more effective to mitigate anhydrite dissolution under alkaline conditions, as per designs determined through reactive transport modeling and subsequent experimental evaluation.

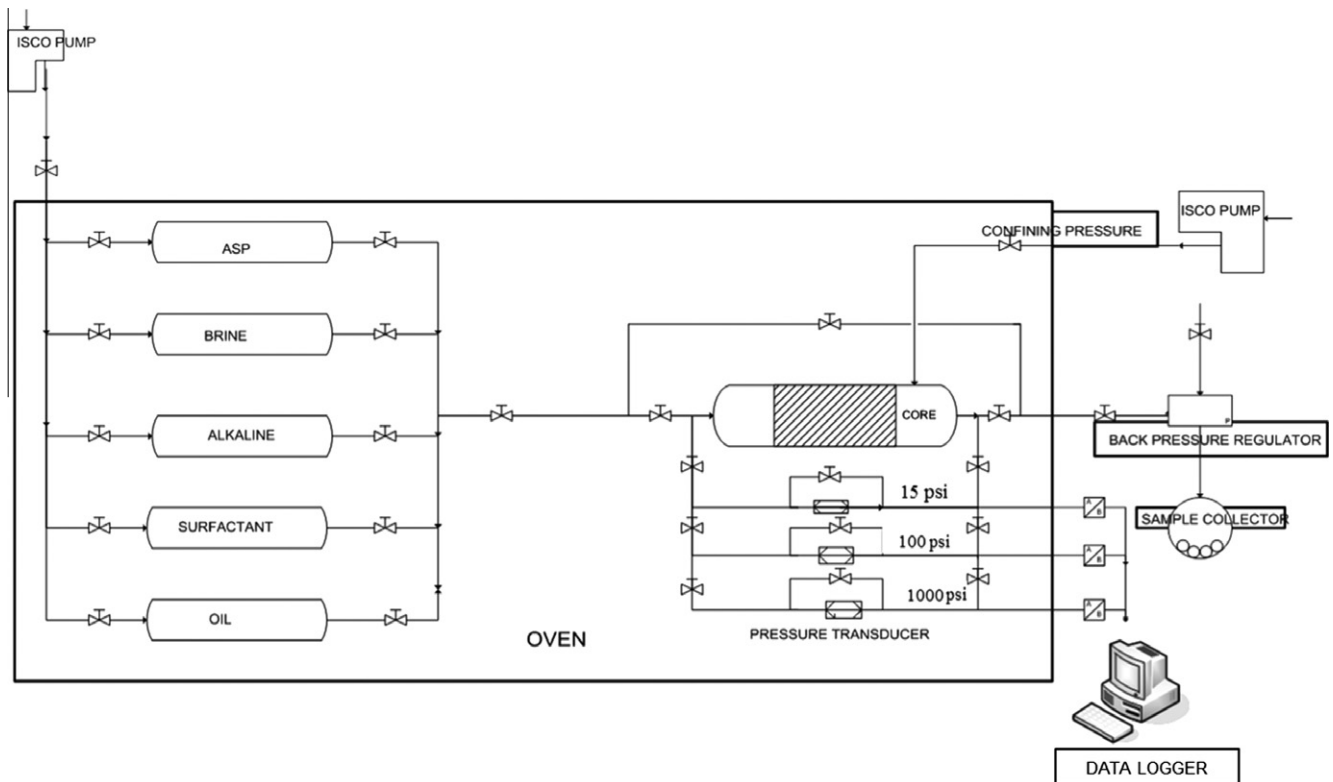


Fig. 1. Coreflooding setup schematics.

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