EOR Field Experiences in Carbonate Reservoirs in the United States

Summary

A considerable portion of the world's hydrocarbon endowment is in carbonate reservoirs. Carbonate reservoirs usually exhibit low porosity and may be fractured. These two characteristics along with oil-to-mixed wet rock properties usually result in lowered hydrocarbon recovery rates. When enhanced oil recovery (EOR) strategies are pursued, the injected fluids will likely flow through the fracture network and bypass the oil in the rock matrix. The high permeability in the fracture network and the low equivalent porous volume result in early breakthrough of the injected fluids. Infill drilling programs and well conformance strategies—mostly gas and water shutoff—have been effectively used to mitigate the early breakthrough and increase oil recovery. In most cases, however, 40 to 50% of the original oil in place (OOIP) is not produced.

A large number of EOR field projects in carbonate reservoirs have been referenced in the literature since the early 1970s. These field projects demonstrate the technical feasibility of various EOR methods in carbonate reservoirs. However, because of the collapse in oil prices, most of the aforementioned project plans have been abandoned. This paper presents a comprehensive compilation of EOR (Gas, Chemical, and Thermal methods) field experiences in carbonate reservoirs within the US, as an attempt to identify key variables and project design parameters for future evaluation and revitalization of mature carbonate reservoirs.

Carbon dioxide flooding [continuous or water-alternating gas (WAG)] is the dominant EOR process used in the US. This is because of the high availability of low-cost CO2. CO2 EOR in particular represents the logical first step towards viable geologic carbon storage and sequestration. EOR chemical methods in carbonate reservoirs, especially polymer flooding, have been widely tested in US carbonate reservoirs. However, EOR chemical methods have made a marginal contribution, relatively, in terms of total oil recovered.

Our study includes a brief overview of current laboratory (e.g. wettability changes and novel chemical additives) and field (e.g. injectivity enhancement) experiences in EOR chemical methods in carbonate formations. A brief discussion surrounding the screening methods used to identify viable EOR opportunities in carbonate fields based on past and present experiences is also included.

Introduction

Carbonate reservoirs are naturally-fractured geologic formations characterized by heterogeneous porosity and permeability distributions. In the case of low porosity and low permeability carbonate rocks (more specifically rock matrices), the fluid flow in the reservoir can be completely dependent on the fracture network while the matrix only plays a source role (analogous to tight sand formations and natural gas flow). In the case of porous carbonate rocks, fracture networks can cause uneven sweeping of the reservoir, leading to early breakthrough of injected fluids in the producing wells and resulting in low recovery factors. The abundance of carbonate reservoirs has been the subject of numerous studies attempting to characterize their heterogeneities, classify different types of fractured reservoirs, and determine how rock and fluid properties have an impact on ultimate recovery (Roehl et al. 1985; Allan and Qing Sun 2003; Carr et al. 2001; Grave et al. 2000; Benson et al. 1998; Wardlaw 1996).

The TORIS database (maintained by the US Department of Energy) indicates 22% of the OOIP in the US is contained in shallow-shelf carbonate reservoirs. Currently in the US, these types of reservoirs exist in more than 14 states with over 70% of the OOIP located in reservoirs in Texas and New Mexico, mostly concentrated in the Permian Basin (Nuckols 1992, Xie et al. 2005). Over the last three decades, primary production, waterflooding, and CO2 floods, combined
References


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For nearly a half century, in a practice called enhanced oil recovery (EOR), carbon dioxide has been used to extract additional oil from developed oil fields in the United States. U.S. companies are also investing in new technologies to re-use captured carbon emissions in innovative ways, including jet fuel and automobile seats. This natural gas processing plant serves ExxonMobil, Chevron, and Anadarko Petroleum CO2 pipeline systems to oil fields in Wyoming and Colorado and is the largest commercial carbon capture facility in the world at 7 million tons of capacity annually. 1996: Sleipner CO2 Storage Facility offshore of Norway. This project captures CO2 from gas development for storage in an offshore sandstone reservoir. It was the world’s first geologic storage project. The paper discusses the Enhanced Oil Recovery Project, the progress of the CO2 flood, and the goals of the Monitoring Project. Particular emphasis is placed on understanding how the monitoring project will help determine the capacity of oil reservoirs to retain CO2 for the long-term. Figure 1 Introduction: Weyburn Field is a major oil field in southeastern Saskatchewan, Canada. The oil is located in a carbonate reservoir of Mississippian age with an upper seal of anhydrite. Initial oil in place is estimated at approximately 1.4 billion barrels, making this a significant field by world standard.