Successful CO_2 flooding in Bakken reservoirs: understanding the vital role of geochemical and geophysical interactions

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Summary

The Upper Devonian-Lower Mississippian Bakken Formation of the Williston Basin is an important hydrocarbon reservoir. In the Canadian Province of Saskatchewan, it is estimated that Bakken Formation reservoirs are endowed with some 25 to 100 billion barrels of original oil in place. The primary recovery factor in the various Bakken Formation lithologies, however, remains rather low due to a high degree of capillary trapping. Furthermore, the rate of primary production is known to decline drastically over the first one-two years of operation. Enhanced oil recovery methods are considered key to the further development of the significant resources within Bakken reservoirs. While water-flooding could result in unfavourable injectivity issues, carbon dioxide (CO_2) miscible flooding provides a promising option for significantly boosting the recovery factor.

The Middle Member of the Bakken Formation, that is oil-bearing, has extreme lithological variability both vertically and along strike; it is commonly also host to highly saline formation brines. Complex geochemical reactions from CO_2-rock-brine interactions under reservoir conditions - and the many physical and chemical processes that are expected to result - have to be accounted for in any design of a CO_2 flooding process in Bakken reservoirs. For example, reaction of CO_2-saturated brine with calcite, dolerite and/or anhydrite cements may result in grain dissolution, framework-repacking and fluid-compositional changes, that ultimately affect rock permeability and porosity. As well, carbonic acid may react with cations present in formation brine to precipitate new carbonate mineral cements. These two mechanisms can induce both positive and adverse effects on reservoir behaviour and CO_2 flooding performance.

In this research, complex interactions among CO_2, rock, and brine in Bakken reservoirs were investigated and presented. Experimental, CO_2 core-flooding was conducted on Middle Member core plugs that represent a variety of lithologies and mineralogies present within the Bakken Formation (including siltstone, sandstone, and dolomitic/calcitic sandstone). Samples were immersed in formation brine, saturated with CO_2 for various periods of time of up to four months in duration. Scanning electron microscopy-energy dispersive spectroscopy (SEM-EDS) and X-ray diffraction (XRD) were performed to analyse morphological and mineralogical changes on pre- and post-flood core samples. Experimental results highlight important modifications to both grain-framework and the pore cements, particularly where this is calcite, or the lithology contains pyrite. For example, the leaching of pyrite in some samples was observed to have occurred after less than two weeks sample immersion. Following longer periods of saturation, calcite

cements were observed in various stage of dissolution (see Figure 1, below), whereas sandstone samples that were dolomite-cemented appear unaffected under identical conditions. The data point to a need to understand more fully the implications of fluid–rock interactions that could affect porosity, permeability, relative permeability, and wettability, which will help oil producers determine the viability of, and select optimal locations for, CO_2 flooding in Bakken Formation reservoirs.

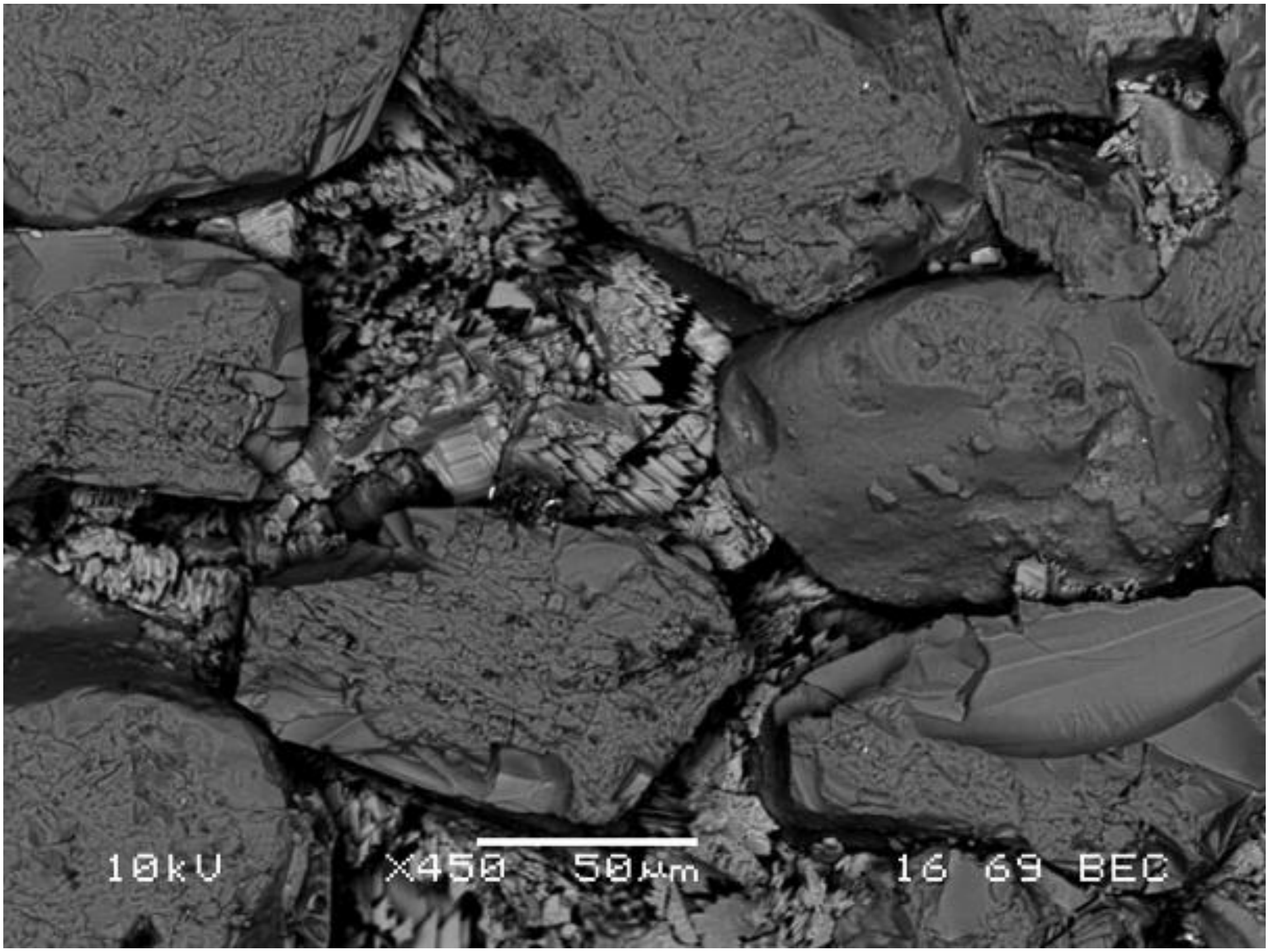

Figure 1. Back-scattered electron image illustrating the dissolution of cementing calcite (light grey) following experimental CO_2 core flooding of a Middle Midale member core plug (Bakken Formation sandstone). Detrital grains (dark grey) include quartz and K-feldspar. Scale bar represents 50 μm.