Marine and Petroleum Geology 44 (2013) 41–59

Contents lists available at SciVerse ScienceDirect

Marine and Petroleum Geology

journal homepage: www.elsevier.com/locate/marpetgeo

Reservoir characterization of a "tight" oil reservoir, the middle Jurassic Upper Shaunavon Member in the Whitemud and Eastbrook pools, SW Saskatchewan

Julianne Fic, Per Kent Pedersen*

University of Calgary, Department of Geoscience, Calgary, Alberta T2N 1N4, Canada

ARTICLE INFO

Article history:
Received 9 February 2012
Received in revised form
4 March 2013
Accepted 18 March 2013
Available online 3 April 2013

Keywords:
Reservoir characterization
Shoreface sandstones
Low viscosity oil
Horizontal well
Hydrological fracturing

ABSTRACT

New horizontal drilling and multi-stage fracture completion technology have proven successful in unlocking hydrocarbons from previously uneconomic reservoirs. In this paper, we investigate the application of this new technology to a medium gravity oil sandstone reservoir to enhance the poor oil recovery within the pool but also to evaluate if the pool boundaries can be expanded. Petrophysical well-logs were integrated with detailed core descriptions, thin sections and core analysis data to provide insight to the reservoir characteristics and factors controlling production, reservoir distribution, depositional environments and lateral extent of depositional fairways for the reservoirs.

The middle Jurassic Upper Shaunavon B sandstone is the main reservoir in the studied Whitemud and Eastbrook pools in southwest Saskatchewan. The reservoirs are composed of mixed siliciclastic/carbonate, shallow marine shoreface deposits which have a strike trend northeast–southwest. Although the pools were discovered in 1953 and 1966 and have cumulative production of 3.3 MMBbls of medium gravity 22 API oil, estimated oil recovery is less than 4%.

The Upper Shaunavon B sandstone has two main reservoir facies, shoreface sandstones with permeabilities in the 0.1–10 md range and relatively thin but high permeability (10–1000 md) coquina beds. Until recently, wells targeted mainly the high permeability coquina for its higher production rates and as a means to drain the associated thick, lower permeability shoreface sandstone reservoir.

This study evaluates the Upper Shaunavon B shoreface sandstone reservoir quality by examining the reservoir properties, heterogeneity, connectivity, and pore volume of the flow units based on core and petrophysical data. Comparison of production data from wells intersecting both facies of the Upper Shaunavon B versus wells where the underlying high permeability coquina facies is absent allows a perspective on the impact that the coquina has on the recovery factor in both reservoir types.

Integration of petrophysical well-logs, detailed core descriptions, thin sections and core analysis data provide insight to the facies interpretation, reservoir distribution and lateral extent of depositional fairways for both units. Reservoir characterization of the lower permeability siliciclastic facies at the Whitemud and Eastbrook pools, coupled with recent advances in horizontal drilling and completion technology show that additional drilling opportunities exist within the pools to improve oil recovery, but also that oil-saturated sandstone reservoirs exist outside the boundaries of the pools. Recent successes with multi-stage fracturing of horizontal wells have confirmed the findings of this study.

1. Introduction

The horizontal drilling and multi-stage fracture completion technology that unlocked large gas reserves from shale gas reservoirs, have also successfully been applied to relative low porosity and permeability oil reservoirs, such as the Bakken Formation in the Williston Basin and Cardium Formation in the Alberta Basin. The hydrocarbons within these reservoirs are relatively high viscosity, high gravity oil. Application of the technology to lower viscosity, medium gravity oils has been limited and has mainly targeted high permeability reservoirs, e.g. ooid banks within the Lower Shaunavon in the Williston Basin. This study presents a reservoir characterization of the Upper Shaunavon shoreface

* Corresponding author. Tel.: +1 403 220 8454; fax: +1 403 284 0074.
E-mail addresses: jdfic@ucalgary.ca (J. Fic), pkpeders@ucalgary.ca (P.K. Pedersen).

0264-8172/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.marpetgeo.2013.03.013

sandstones and proposes the existence of an additional shoreface trend between the Whitemud and Eastbrook oil pools. The study evaluated the application of horizontal drilling and multi-stage hydraulic fracturing to a moderate porosity and permeability, medium gravity oil, sandstone reservoir of the middle Jurassic Upper Shaunavon Formation. The unconventional lower and upper Shaunavon members have become economically viable targets and have produced 1.3 million barrels of oil since 2009 (Government of Saskatchewan, 2011).

The Shaunavon Formation has been an oil producer for over 50 years in southwestern Saskatchewan, Canada. Initial production was from the Delta field in 1952 followed by production from the Eastend field in the same year (Marsh and Yurkowski, 2008). To date, approximately 2385 wells have been drilled with production from the Shaunavon Formation in southwestern Saskatchewan. This study presents the reservoir characterization of the unconventional, tight oil reservoir of the Upper Member of the Shaunavon Formation. The Shaunavon Formation was initially targeted as a conventional resource, but is currently being exploited for its unconventional oil resources. Characterizing the Shaunavon reservoir will provide insight for future optimal horizontal drilling programs and may be applied to similar tight oil reservoirs in basins around the world and provide access to large untapped oil reservoirs.

The studied Whitemud and Eastbrook pools (Fig. 1) had, until recently, only been exploited by vertical wells. At present, the Whitemud Pool has a well count of 58 oil wells (55 currently active) and 17 horizontal wells. The Eastbrook Pool has a well count of 36 oil wells (28 active) and 4 recently drilled horizontal wells. Improvements in completion technology, including fracturing, perforating and acidizing the reservoir currently yield increased production rates. These new technologies may be used to target the lower permeability Upper Shaunavon B shoreface sandstones.

Reservoir characterization involves analysis of rock properties with a focus on the influence of facies on production. To properly understand the heterogeneity of the Upper Shaunavon B reservoir and its distribution, this study focuses on three elements: 1) integration of the core data with log data to define fairways and facies, 2) description and definition of the sedimentary facies and their interpretations based on core observations, and 3) characterization of the reservoir through mapping, volumetric analysis and production data. The objectives of the study are to define the reservoir depositional trend, and to determine the pore volume and upside potential within the pools as well as any expansion of the existing pool boundaries.

2. Regional depositional setting

Deposition of the Upper Shaunavon Member occurred along the western flank of the Williston Basin on the Swift Current Platform (Christopher, 1966a,b). The Swift Current Platform formed the stable northwest part of the basin, with a shallow marine succession recording a complex history of sea level fluctuations (Poulton et al., 1994). The Shaunavon oil trend is located along the southwestern flank of the Shaunavon "half-graben" marked by a series of normal faults that form the up-dip trap to some of the Shaunavon oil pools (Can. Discovery, 2009) (Fig. 1). The Shaunavon "half-

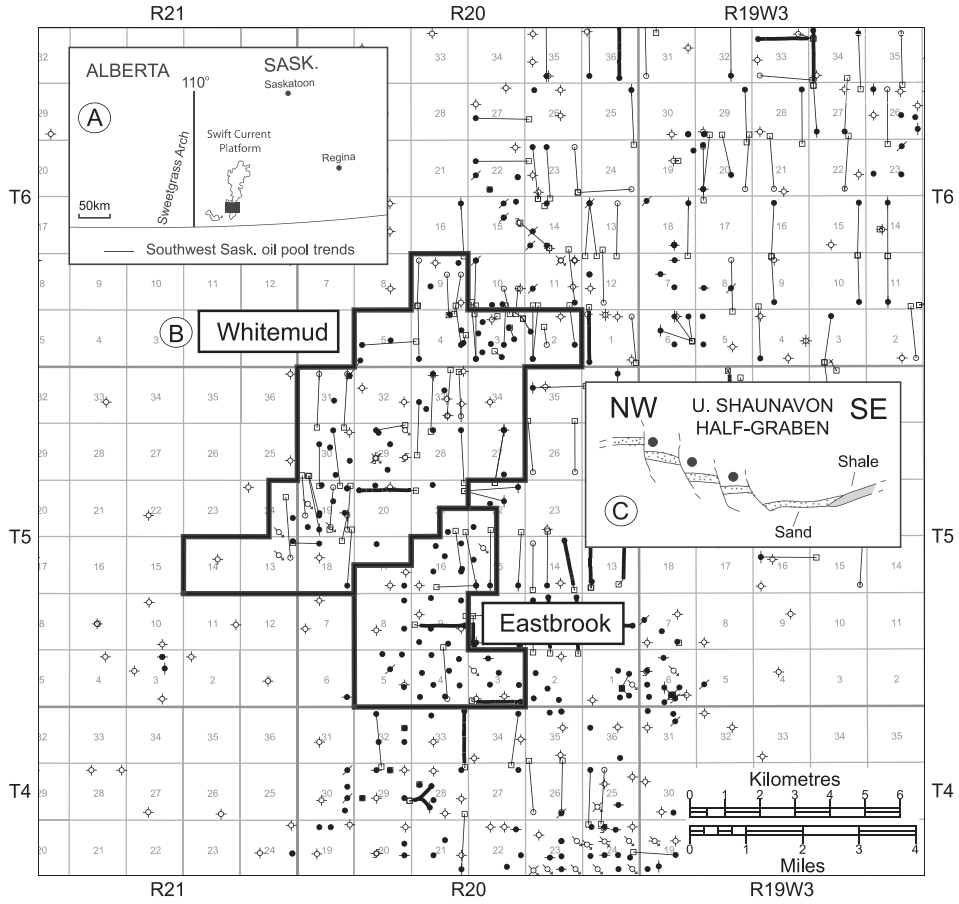

Figure 1. (A) Map of Alberta and Saskatchewan showing the southwestern trend of the Shaunavon oil pools, middle Jurassic tectonic elements and major cities (modified from Poulton et al., 1994). (B) Enlarged map of the study area in southwest Saskatchewan showing the outline of the Upper Shaunavon Whitemud and Eastbrook pools. (C) Schematic drawing of Shaunavon "half-graben" and normal faults (Can. Discovery, 2009). The black dots represent Upper Shaunavon oil production.