Provost Cummings 'I' Pool: Using a 3D Reservoir Model to Better Understand Reserves and Production

Gela Crane, Len Stevens, Lisa Griffith – PanCanadian Petroleum Ltd.
Jacques Millette – STA Consulting and Bob Wytsma – Landmark

INTRODUCTION

The Provost Cummings 'I' pool located in Twp. 40, Rge. 3W4 (fig. 1), has produced over 4.3 x 10^6 m^3 of 22 API oil from the Cummings and Dina Formations (lower Cretaceous, mid Mannville) since 1983. In 1998/99 it was determined that the Cummings 'I' pool was not performing as predicted. The majority of the wells were producing at a high water cut earlier than expected. Additionally, well production characteristics varied considerably both locally and on a pool-wide scale. To further complicate matters, an aggressive infill program implemented in 1997/98 encountered anomalous (original) oil-water contacts within the pool. To better understand this complex reservoir behaviour, a detailed 3D geological model of the Cummings 'I' pool was created. The model illustrated the facies distribution, and helped visualise fluid behaviour and communication. Furthermore, diagenetic calcite associated with the water/oil contact was spatially mapped, and proved useful in understanding puzzling water production histories between otherwise similar wells. Ultimately, the model helped the team make more informed decisions on the best reservoir optimisation strategy for the Cummings 'I' pool.

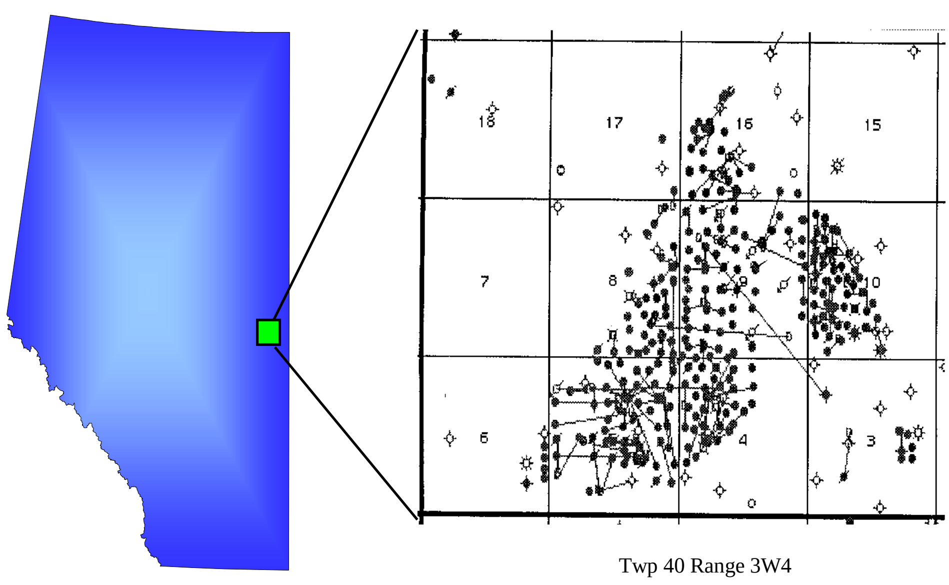

Figure 1: The Cummings 'I' pool located in Twp. 40, Rge. 3W4, east central Alberta

GEOLOGICAL FRAMEWORK AND DEPOSITIONAL MODEL

Detailed core and log interpretation has differentiated eight facies, in two formations (Cummings and Dina)(Fig. 2). These facies were repeated in a series of transgressive fluvial-estuarine and shoreface environments over four sea level cycles. The reservoir units within the Cummings ‘I’ pool comprises six geologically and petrophysically distinct facies found within three crosscutting fluvial-estuarine channels and two shoreface systems. The reservoir characteristics of these facies affect both the production characteristics and the reserves of any given well in Cummings ‘I’, The pool is trapped by an updip shale channel, and sealed by an overlying paleosol and coal sequence.

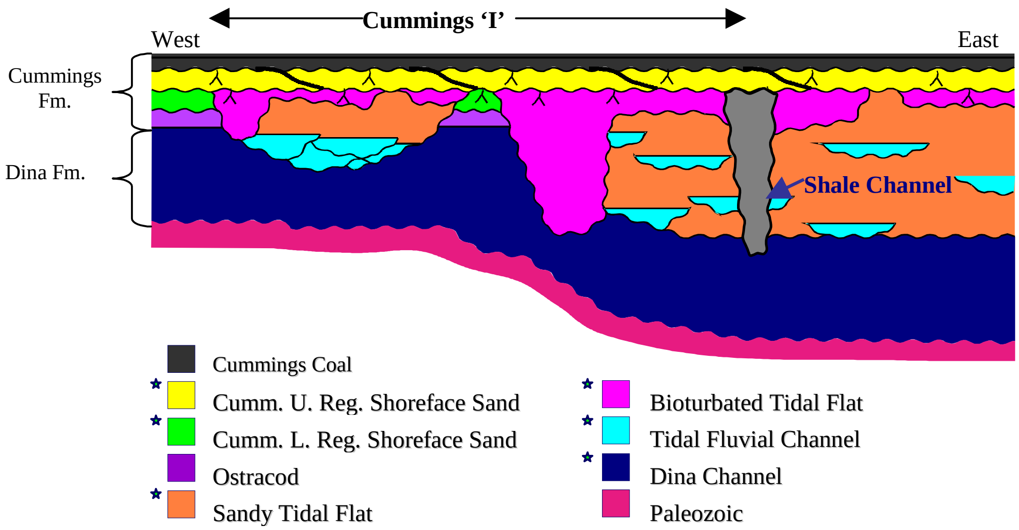

Figure 2: Cross-sectional cartoon of the Cummings ‘I’ pool. The pool is comprised of six reservoir facies found in three interpreted fluvial-estuarine channels and two shorefaces. The pool is trapped by an updip shale channel and sealed by an overlying paleosol and coal sequence. Asterisks denote reservoir units.

RESERVOIR CHARACTERISTICS

The detailed 3D geological model allowed us to visualise and better understand the many different forms of reservoir compartmentalisation that occur both locally and regionally over the Cummings ‘I’ pool. On a large scale, the pool is compartmentalised vertically. The lower producing reservoir within the Cummings ‘I’ pool is channel-dominated. It is separated from an upper regional (shoreface) sand unit by a laterally continuous, meter-thick paleosol. This paleosol effectively cuts off communication between the top and bottom of the pool and causes them to produce as separate entities. The lower portion of the pool has a natural water drive provided by a large aquifer situated in the Dina channel sandstone (Fig. 2). In contrast, the upper regional sand unit is not in communication with the aquifer and must receive water flood pressure support.

On a finer scale of compartmentalisation, the lower, channel-dominated part of the reservoir can be subdivided into a number of flow units and baffles. Detailed core, petrological and petrophysical analysis show that depositional environment had a profound effect on the reservoir quality of each facies (Fig. 3). In the lower channel-dominated portion of the pool, the two older channels (Dina fluvial channel facies, Cummings tidal fluvial and tidal flat facies, Figure 2) all are good to excellent in quality. We would predict good fluid communication between these three facies, making them excellent flow units.

In contrast, there were two baffles mapped in Cummings ‘I’. The first is facies controlled. The youngest channel in the lower portion of Cummings ‘I’ was back-filled with highly variable moderately bioturbated sands and shales. The bioturbated nature of this facies causes it to have an erratic porosity-permeability relationship over very short distances (Fig. 4), inhibiting fluid communication both within the facies, and between it and the underlying channel facies. Furthermore, the bioturbated channel-fill unit may hinder horizontal communication between the main body of the Cummings ‘I’ pool and the lobe found to the east (Fig. 1). Understanding the spatial distribution of this unit, and the amount penetrated by each well bore explains some of the production variations within Cummings ‘I’. The second ‘baffle’ unit in Cummings ‘I’ is the numerous discontinuous diagenetic calcite layers that are associated with the paleo-oil/water contact in Cummings ‘I’. Water cuts and production history associated with the wells in the do not appear to be controlled solely by the dominant facies penetrated in each well. 3D mapping of the calcite distribution along the oil/water contact and history matching well production to the density / presence of calcite illustrates and additional factor influencing the complex production profiles.

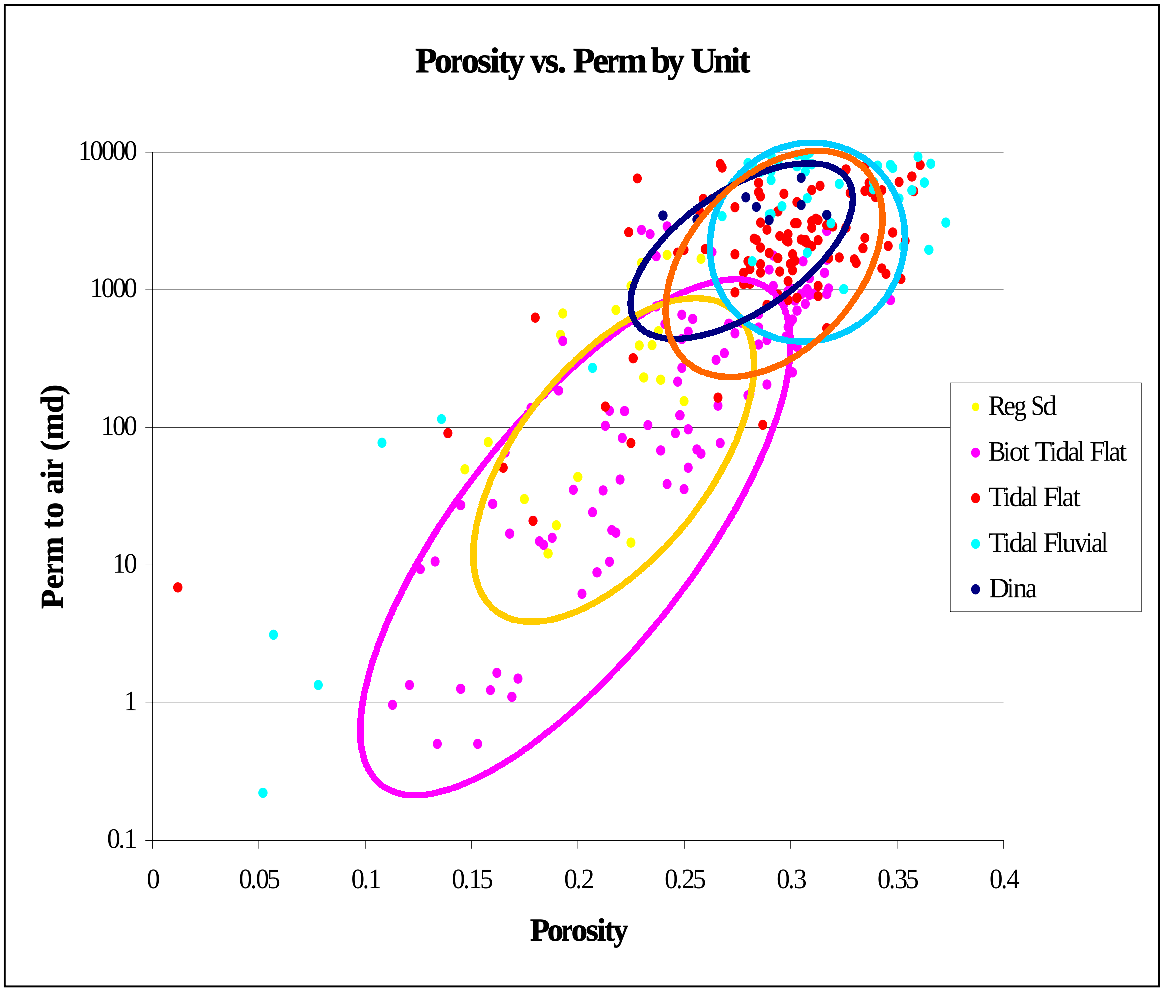

Figure 3: Core porosity vs. permeability for each main reservoir unit. The difference in reservoir quality between the Bioturbated Tidal Flat unit and the underlying Dina, Tidal Flat and Tidal Fluvial units, causes intermittent communication between these sets of facies, translating into different production characteristics dependent on the amount of each facies penetrated.

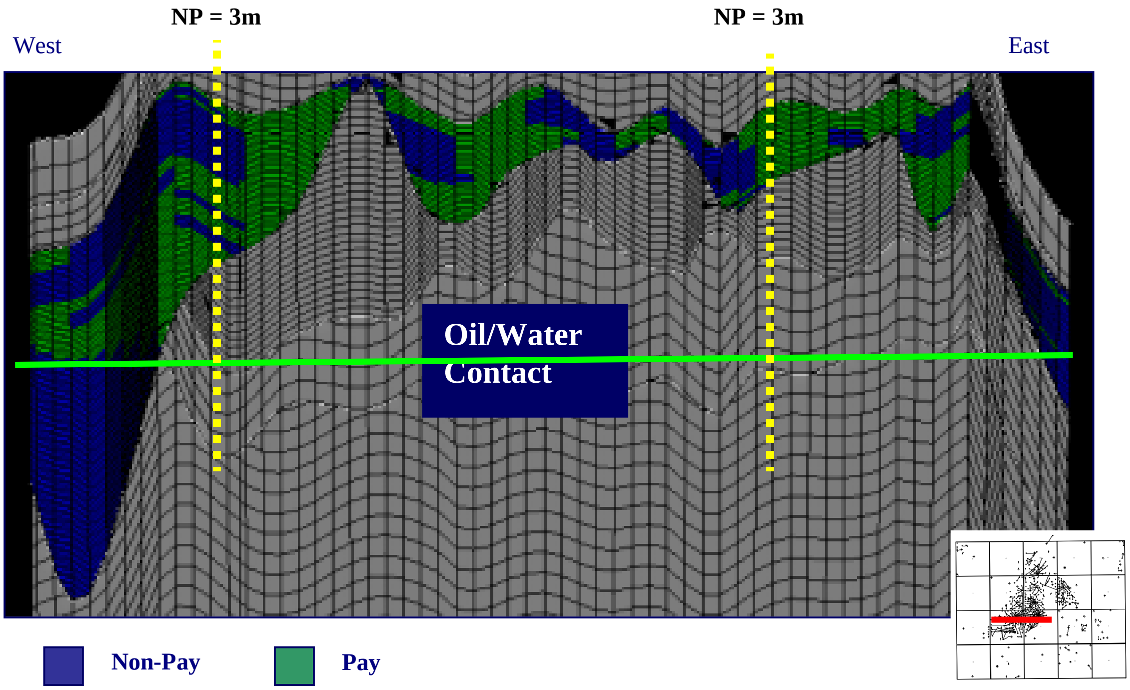

Figure 4: Structural cross-section from 3D geological model. The highlighted horizon is the bioturbated channel-fill facies. Based on cut-offs imposed to determine minimum reservoir quality in this facies, the green highlighted cells represent reservoir quality rock with this facies (above the oil/water contact). Blue highlighted cells represent non-reservoir quality rock, above the oil/water contact. Note that the extreme variability is based on 200 to 400m well spacing.