[PS]The Cardium Formation Production and Injection Database. Gas to Oil Ratios, Production Forecasting and GOR Risk Assessment*

C.A. Rojas-Aldana[1], F.F. Krause[1], and R.O. Meyer[1]

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[1]Geoscience, University of Calgary, Calgary, Alberta, Canada (crojas@live.ca)

Abstract

The Cardium Formation has been one of the most important Cretaceous hydrocarbon exploration and production targets in the Province of Alberta for the last 60 years. Most fields reached maturity in the early 1970's; however with the debut of multi-stage horizontal drilling and the successful completion in 2008 of the well Bonterra Nexstar 4-25-47-03W5/1-25-47-03W5, excitement in the formation was restored. In spite of the increase in drilling activity in exploratory halos of the fields, the recent developments have been inconsistent because some wells end up in zones with very high Gas to Oil Ratios (GOR). In part this has been the result of wells having been positioned too close to existing oil producing zones. On the other hand, unexpectedly high GOR have also been encountered at approximately the same stratigraphic level across areas were previous drilling and production was sparse. These difficulties arise in significant measure because there is much more limited geological understanding of these marginal areas. In this study, we are characterizing GOR trends, working on production forecasts and developing a GOR screen capable of assessing exploration risk. For that purpose, we have compiled a production & injection database with 15626 non-commingled wells. Risk assessment begins with the recognition of production values in the third month (IP3) versus net-pay cut offs, overall field performance and the postulation of a mappable variable to avoid areas with high GORs. Highlighted among the results is the recognition that production of horizontal wells demonstrates bypassed pay and compartmentalization in the legacy areas of most fields, early stage production forecasting from horizontals is much more difficult to predict than late stage production and that GOR behaviour can be assessed if tested against net pay, IP3, core and lithofacies distributions in the subsurface. The methodology developed here can be applied to any field in Alberta targeting the Cardium Fm. reservoir.

THE CARDIUM FORMATION PRODUCTION AND INJECTION DATABASE. GAS TO OIL RATIOS, PRODUCTION FORECASTING AND GOR RISK ASSESSMENT

GEOSCIENCE, UNIVERSITY OF CALGARY
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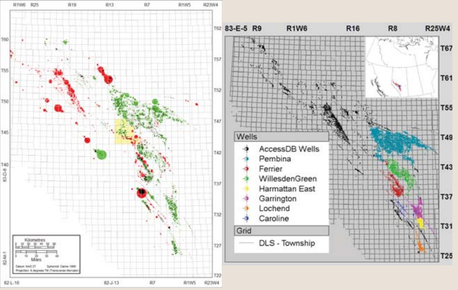
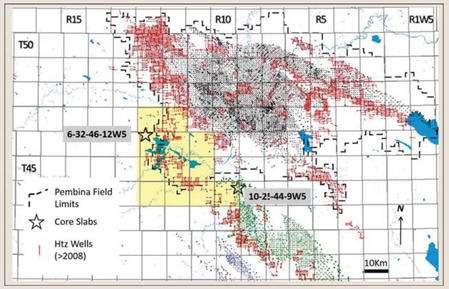
SUMMARY

This study explores the general production trends of Cardium Fm. wells with contrasting GOR values. These wells are located in the periphery of most producing fields in AB.



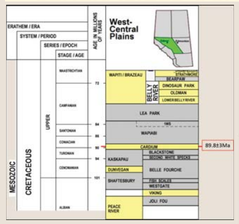
Land coverage of the Cardium Fm in Alberta, Canada. Shown are seven of the largest fields from which the formation is targeted. The largest field is Pembina with an approximate areal coverage of 5800 km sq.

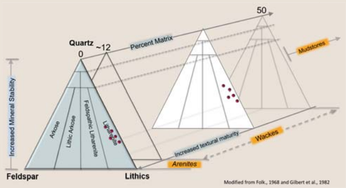


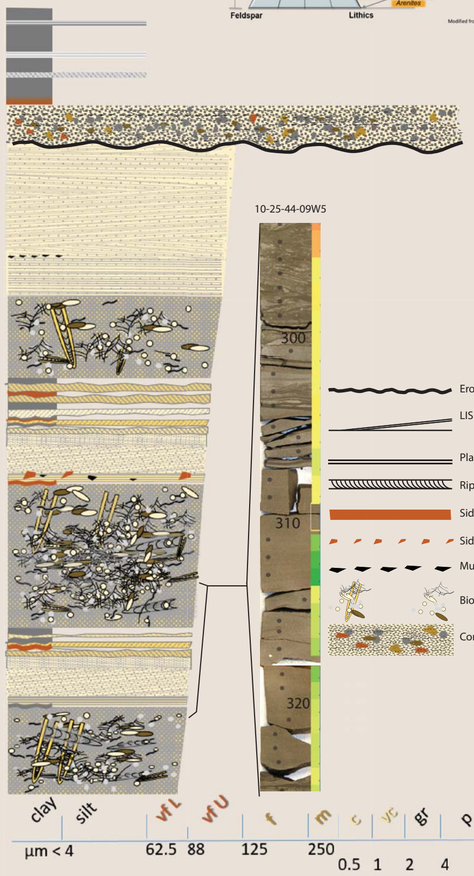
Sample Cardium Fm. wells with contrasting GOR values

10-25-44-09W5	F12MoGOR -> 25000 scf/bbl
06-32-46-12W5	F12MoGOR -> 691 scf/bbl

CORE DESCRIPTION - GENERALIZED SCHEMATIC STRATIGRAPHIC COLUMN







PRODUCTION DATABASE AND GOR

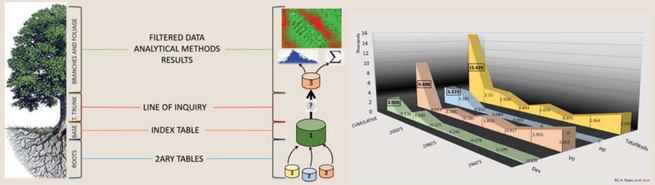
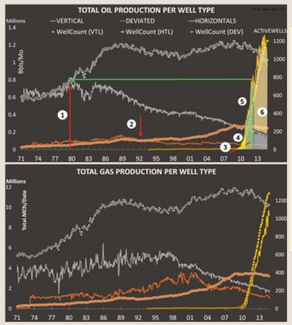


Illustration of the database framework used for the analysis of the Cardium Fm. production dataset. Data is organized and sorted according to a hirarchy of attributes that identifies a well across the database structure. The structure facilitated the navigation and extraction of the information used in the characterization of gas to oil ratios.

Frequency plots illustrating the total number of wells with recovery rates below the Alberta average of 118 barrels of oil per day in the third month of production (IP3). The plot compares the performance of multistage, fractured, horizontally drilled wells in seven of the largest oil & gas fields in Alberta. The fields are Caroline, Ferrier, Garrington, Harmattan East, Lochend, Pembina, and Willisden Green. Sixty percent of the well populations in the Caroline, Harmattan East, and Lochend fields have performed better than the expected value.

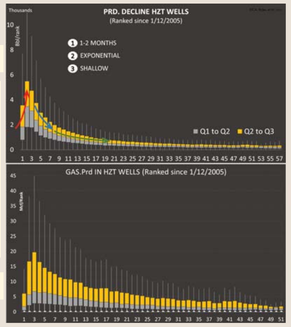
PRODUCTION TRENDS



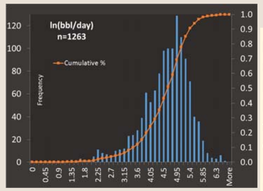
Historical and cumulative oil & gas prd. trends according to wellbore trajectory. 1)Pressure and resource depletion outpaced prd. rates in 1979. 2) A similar downturn in the productivity of deviated wells observed in 1989. 3) First horizontally, fractured, multistage well completed in the Pembina field. 4) 200 horizontal wells outpace the production of over 1000 verticals in less than two years. 5) Slightly less than 800 horizontals matched production levels not reached since 1979. 6) Production of verticals amount to one sixth of that of horizontals

PRD. DECLINE HORIZONTALS

Oil and gas production decline models of the expected prod. life of a modern multistage, fractured, horizontally completed well in the Cardium Fm. Three stages are characteristic. 1) Exponential flow back stage during months one and two . 2) Exponential downturn in productivity lasting an average of six months. 3) Long term shallow harmonic decline in productivity

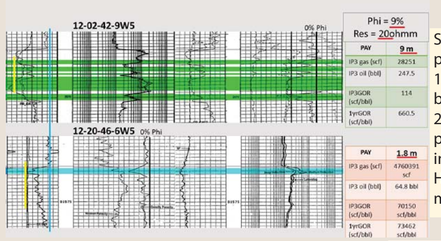


AB AVG OIL PROD & IP3, HZTLS



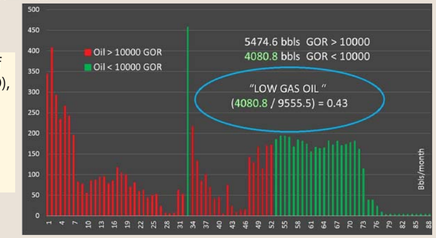
Distribution of the avg oil prod. values in the third month (IP3) as gathered from 1263 multistage fractured, horizontally drilled wells. The data shows a near natural-log character in which 134 barrels of oil per day represent the mode of the distribution. The characterization of the GORs was completed in relation to the province wide mean and median, calculated at 118 and 102 barrels of oil per day respectively

NET PAY VS. IP3



Suite of Gamma Ray (GR), Resistivity, and Density porosity logs used to calculate net pay in wells 12-02-42-9W5 and 12-20-46-6W5. The calculation is based on a porosity and resistivity cut-off of 9% and 20 ohmm respectively. The logs reveal contrasting petrophysical properties emphasized by differences in the shale factor (GR) and the density porosity log. High GOR values correlate with wells with less than 4 metres of net pay

Illustration of the steps involved in the calculation of a mappable variable, designated as 'low gas oil' (LGO), capable of high grading the location of areas with high exploration risk in the Cardium Formation. LGO is the ratio of the cumulative oil production under low gas flow rates and the cumulative oil produced over time.



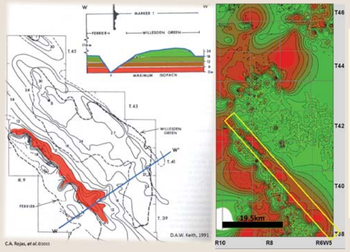


Illustration of a contoured map of the 'LGO' – Low Gas Oil - variable that screens for and high grades areas with elevated GORs in the Cardium Formation. The map colour codes in shades of red areas that should be avoided during exploration. The results correlate with a map that illustrated an interfield isopach low that separates the Ferrier and Willisden Green fields. The interfield low is caused by deep scouring of the uppermost Cardium A unconformity and it has been found to be underlain by siltstones and wackes (Keith, 1991).

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