UNCONVENTIONAL OIL RESERVES DEVELOPMENT IN THE VIKING PLAY (WESTERN CANADA) USING HORIZONTAL WELLS AND HYDRAULIC FRACTURING

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Abstract. Oil production from the Viking play in Saskatchewan province started in the 1950s and continues since that time. Horizontal drilling and multistage fracturing have caused resurgence in development of this play. Based on the production data from several fields, the comparative results of the Viking play development using vertical and horizontal wells are presented. Horizontal wells drilling made it possible to increase oil production in those formation zones that were previously considered predominantly gas-saturated, as well as in the zones affected by water injection using vertical wells in order to maintain reservoir pressure. Infill drilling combined with longer lateral completion length also positively affected the development of oil reserves from the Viking play.

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The Viking play ranges from east-central Alberta to west-central Saskatchewan with most activity concentrated in Dodsland and Kindersley fields in Saskatchewan and Halkirk-Provost fields in Alberta. According to Canadian experts, original oil in place in this play ranges from 3-4 to 6 billion barrels of oil. Oil production from this play was started in the early 1950s but was revived with the improvement of horizontal drilling technology combined with multistage hydraulic fracturing.

This play, which actually covers most of Saskatchewan, consists of interbedded fine sandstones, siltstones and mudstones, bracketed by two shales. The upper layer is two to three meters thick while the lower is three to nine meters thick.

The distinctive factors of geological structure of this play are the following:

Net to Gross reservoir ratio is difficult to determine using log evaluation because of the rock characteristics; geophysical well logs not advanced enough to accurately quantify net pay.

Reservoir consists of cm-scaled parallel-laminated and bioturbated oil-bearing sands and interbedded tight shales.

Porosity ranges 15 to 20%, permeability varies from 20 to 80 μm^2 from conventional core analysis and oil density is about 36 degrees API (845 kg/m^3).

Understanding the reservoir in area is paramount to developing a successful horizontal drilling and stimulation program. Combining the best reservoir quality and thickest net pay areas focuses horizontal drilling to the most prospective areas.

As noted above, initially oil production from the Viking play began in the 1950s and its production through vertical wells, mainly from the upper zone, has continued since then. Horizontal wells drilling combined with multistage hydraulic fracturing revived the development of this play as the lower zone became economically more attractive. In the Dodsland and Prairiedale fields, the Viking play lies at a relatively shallow depth – less than 800 meters – which reduces drilling costs; on the other hand low reservoir pressure limits production.

As of mid-2017, more than 35,000 oil wells have been drilled in the Viking play; approximately 27,800 of those wells are vertical or deviated and the remaining approximately 7,500 are horizontal. More than half of all wells (about 20,000) were drilled within Alberta province and the remaining slightly more than 15,000 wells – in Saskatchewan. This proportion is completely different for horizontal wells – almost 80% of all those wells (about 5,800) were drilled within the fields in Saskatchewan province. The main factor that determined such development was that, as noted earlier, the depth of the play within this province is less than 800 meters, which significantly reduces drilling and completion costs for horizontal wells.

The Table 1 shows the main parameters and production data for all analyzed fields. It is worth noting that the total number of horizontal wells drilled in these fields is about 45% of all horizontal wells drilled in the Saskatchewan province targeting Viking play.

Several areas were identified within each of the reviewed fields with different vertical and horizontal wells patterns in each area and for each area several typical production performance profiles for both vertical and horizontal wells were generated.

Characteristics	Unit	Field			
		Dodsland	Kerrobert	Prairiedale	Plato North
Beginning of production	year	1957	1981	1984	1978
Total well	pcs.	4,314	1,807	1,318	876
Vertical wells	pcs.	3,060	1,179	1,147	333
Horizontal wells	pcs.	1,254	628	171	543
Total producing well	pcs.	3,815	1,657	1,318	850
Vertical wells	pcs.	2,597	1,032	1,147	318
Horizontal wells	pcs.	1,218	625	171	532
Total injection well	pcs.	499	150	-	26
Vertical wells	pcs.	463	147	-	15
Horizontal wells	pcs.	36	3	-	11
Initial oil reserves	Million barrels	424.55	238.52	565.24	171.62
Cumulative oil production	Million barrels	113.49	28.99	11.60	18.39
From vertical wells	Million barrels	88.90	20.24	10.13	7.88
From horizontal wells	Million barrels	24.64	8.74	1.47	10.51
Average depth of occurrence	Ft	2,201	2,343	2,438	2,313
Field area	Acre	61,171	41,247	35,966	19,042
Average thickness of play	Ft	8.01	6.50	17.78	8.63
Average porosity	%	22.40	23.00	23.00	23.00
Density of oil	API	36.60	36.60	31.10	32.10
Current oil recovery factor	%	26.7%	12.2%	2.1%	10.7%
Due to vertical wells	%	20.9%	8.5%	1.8%	4.6%
Due to horizontal wells	%	5.8%	3.7%	0.3%	6.1%
Spacing	Acre/well	14.2	22.8	27.3	21.7
Vertical wells	Acre/well	20.0	35.0	31.4	57.2
Horizontal wells	Acre/well	48.8	65.7	210.3	35.1

Table 1

Dodsland Field

This is one of the very first fields where oil production began from the Viking play and at the same time it is the largest field in this play. The first well was drilled on December, 1957 and over the next 30 years it produced just over 30,000 barrels of oil. More than 4,300 wells, including over 3,000 vertical and 1,250 horizontal, have been drilled to the date of the analysis. In some areas of the field, water injection into the reservoir has been implemented to maintain reservoir pressure – and, in particular, water injection has been started also in a number of horizontal wells. The Figure 1 shows vertical and horizontal wells location within Area 1.

Type wells oil production profiles are shown in the Figure 2 for two areas selected, one of which is located in the central part of the field and has approximately the equal number of vertical and horizontal wells (Area 1). The second area is located closer to the southern limit of the field and the results of vertical wells production in this area are significantly worse than those of the

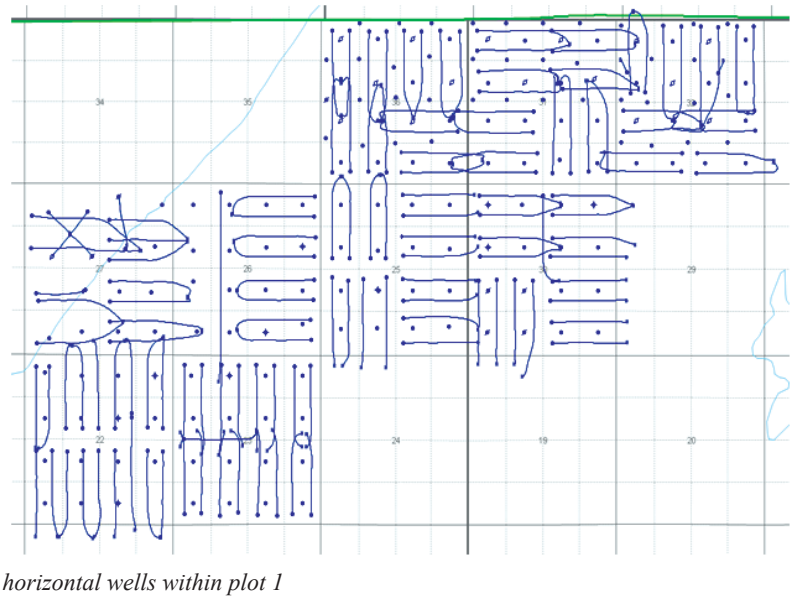

Fig. 1. Layout of vertical and horizontal wells within plot 1

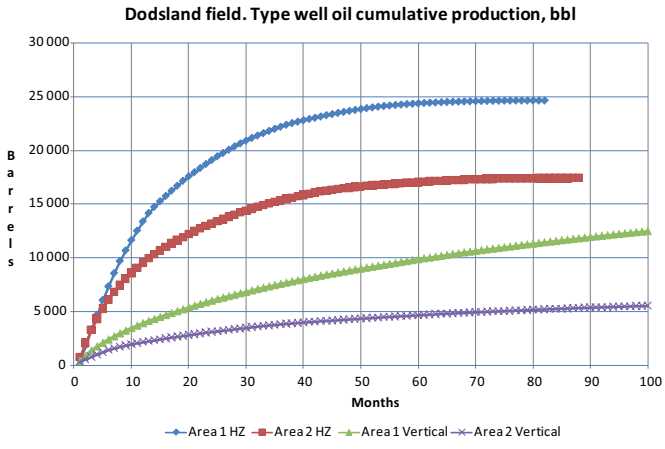

Fig. 2

Area 1. At the same time, for both areas, the results of comparative analysis (Fig. 2) indicate that the horizontal wells are much better than the vertical ones, and the total accumulated oil production for comparable time intervals is 2.5-3 times higher.

Kerrobert Field

The first well in this field was put into operation in May, 1962 and after three years it produced slightly more than 4,500 barrels of oil. The active development of the field began in the first half of the 1980s and to date more than 1,800 wells have been drilled from which a little less than 1,200 are vertical and more than 600 are horizontal wells. For the purposes of this analysis, two areas were selected within the field, one of which (Area 1) was drilled only by vertical wells and there is no water injection within it. In addition to vertical wells, horizontal wells were drilled within the boundaries of the second area and, in addition, injection of water into the play was implemented to maintain reservoir pressure. The Figure 3 below shows cumulative oil production from a typical vertical and horizontal well for each of the selected areas.

As can be seen from the plot, water injection within the second area slightly improved oil production performance from a typical vertical well; however,

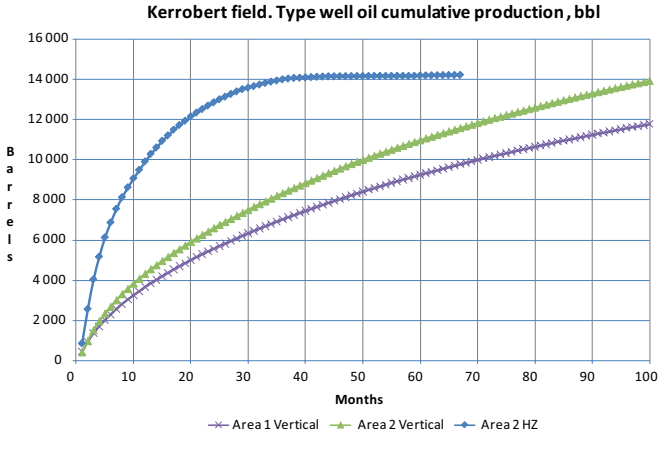

Fig. 3. Cumulative oil production from a typical vertical and horizontal well for each of the selected areas

the horizontal well production profile is significantly higher than the production from vertical wells in both areas. The available data do not allow us to unambiguously assess the degree of influence of the recently implemented water injection into the reservoir to improve the oil production efficiency from horizontal wells.

Prairiedale Field

Development of this field began later than all of other fields analyzed in the present paper – in the mid-1980s – and to date more than 1,300 wells have been drilled with about 1,150 wells to be vertical and more than 150 wells are horizontal. The proportion of horizontal wells as seen from this data is the smallest among all other fields. Three areas were identified within the field, two of which, located in the northern and southern zones of the field, were drilled both vertically and horizontally, while the third one, located between the two previous ones, was drilled only by vertical wells. Another distinguishing feature is the fact that the water injection within the field has not been started until now. The Figure 4 below shows the cumulative oil production over time from typical vertical and horizontal well within each of the selected areas.

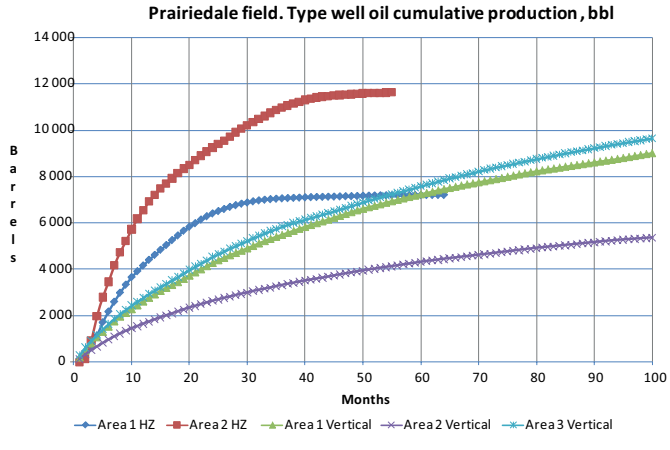

Fig. 4. Cumulative oil production over time from typical vertical and horizontal well within each of the selected areas

The oil production performance for these wells clearly illustrates the earlier statement that the main factor in the effectiveness of horizontal drilling (as well as vertical) and the stimulation methods applied to the reservoir within the Viking play is the geological characteristics and net pays of the formation within the analyzed area.

PlatoNorth Field

The first wells in this field were drilled in the late 1970s, but the active drilling of the northwestern part of the field began in the first half of the 1980s and during 1982-1986 period the entire vertical wells count was drilled. Some efforts to drill vertical wells

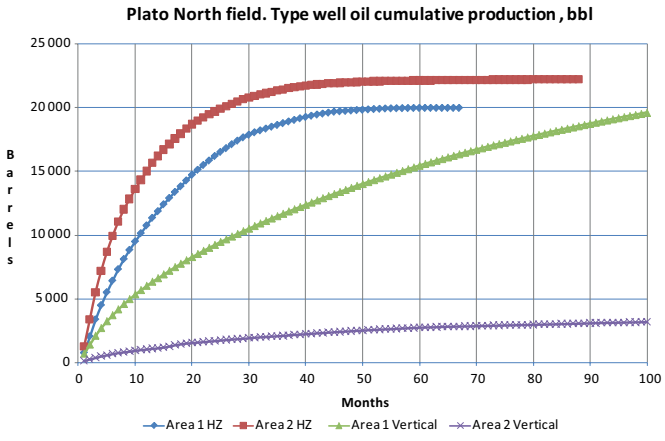

Fig. 5. Cumulative oil production and a typical vertical and horizontal well performance for each of the selected areas

in the southeast direction within the field have not been reasonably successful. Having said that, two areas were selected within the field, one of which was drilled both by vertical and horizontal wells (Area 1) and it covers the northwestern part. The second area is located in the southeastern part where only seven vertical wells were drilled but it did not lead to any noticeable results. In the same time drilling of horizontal wells within this area was much more successful and gets better results. Similar to other fields reviewed before, Figure 5 below shows the cumulative oil production and a typical vertical and horizontal well performance for each of the selected areas.

As can be seen from this data, horizontal wells drilling within Area 2 allowed increasing 7-8 times of recoverable oil volume per well.

In conclusion, it should be noted once again that the development of horizontal well drilling technology in combination with multistage hydraulic fracturing allowed the previously considered low-productive areas and development zones of the Viking play within the Saskatchewan province to be actively developed and recovered. Horizontal wells drilling made it possible to increase oil production in those formation zones that were previously considered predominantly gas-saturated, as well as in the zones affected by water injection using vertical wells in order to maintain reservoir pressure. Infill drilling reducing horizontal wells spacing to 200 meters between wells combined with the longer lateral length (up to 1,500 meters) also positively affected the oil reserves recovery from the Viking play.

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