ANAS Transactions **Earth Sciences** **Special Issue / 2023**

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THE IMPACT OF SHALINESS AND WELL PAIR SPACING IN THE SAGD PERFORMANCE

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Keywords: *shale, thermal, SAGD, bitumen, steam chamber*

Summary. Steam Assisted Gravity Drainage (SAGD) is a common thermal recovery technology that uses steam to heat and extract oil from bitumen reservoirs. It consists of an upper horizontal injector and a lower horizontal producer. Varied lateral extent, thickness, and frequency of shale layers can be observed and these shale layers can substantially impair the pay zone's vertical permeability and slow down the SAGD process by interfering with the flow of steam and oil. Henceforth, identifying shale problems and finding solutions to them has become critical in SAGD production.

This study investigated shale issues in the SAGD process from the simulation perspective. Hypothetical shale cases were built in SAGD simulation models using the CMG STARS simulator. In addition, the vertical well pair spacing in the SAGD simulation model was changed to test it as a remediation technology to reduce the negative shale impact on the steam chamber, and the SAGD performance.

Introduction

In the SAGD process, steam is injected from a horizontal injection well above a horizontal producer. Steam flows horizontally and vertically in the reservoir as a steam chamber is developed as shown in the left side of Figure 1. Due to the injected steam, heat is transferred into the surrounding reservoir and oil in the vicinity of the chamber is heated and its viscosity is reduced, and it is mobilized. It drains, driven by gravity, from the perimeter of the chamber to the production well. The condensate also drains with it.

A significant concern in the development of the SAGD process is the effect of barriers to vertical flow within the reservoir, as in the right side of Figure 1. They may consist of significantly sized shale layers or may be interbedded shale layers that can reduce the vertical and sometimes horizontal permeability.

In this paper, interbedded shales are defined as shales with limited lateral length, i.e. they are not continuous from the beginning of the well to the end point of the horizontal well.

Continuous and extensive shale layers can divide the reservoir and may prevent development of the steam chamber and result in an unsuccessful SAGD operation (Ipek et al., 2008). On the other hand, thin (a few centimeters thick) limited horizontal lengths of shale layers may not severely damage SAGD process performance (Butler, 1996). Inter-bedded shale (IBS) and shale laminates are detrimental to the performance of SAGD and hybrid SAGD/Solvent processes since they reduce, sometimes severely, vertical mobility of the pay zone. Many reservoirs in Athabasca feasible for SAGD or hybrid SAGD/solvent processes have such problems, some of them extensive. Therefore, to improve productivity in these reservoirs, dealing with shale problems has become inevitable and solutions are urgently needed.

The nature and extent of these laminations is not well understood. The current technology for dealing with shale laminations is to inject steam at sufficiently high temperature and pressure so that thermal stresses developed in the reservoir fracture the laminations and disrupt their continuity. Low energy processes under development, including low pressure SAGD will not raise the temperature and pressure sufficiently to disrupt the shale layers. It is therefore necessary to use other methods to fracture the shale laminates.

One obvious approach in dealing with shale problems is to adjust the injection well placement. The problem was first studied in the lab in the late 1980s (Yang, and Butler, 1992). The results have suggested that a higher injector will lead to increased production when intervening shale laminates are present. Most of the subsequent numerical studies have agreed with this assertion (Yuan et al., 2004).

Hypothetical shale cases were built in simulation models. In addition, the well pair spacing in SAGD simulation model was increased to test this approach as a remediation technology to reduce the negative shale impact on SAGD performance. In that case, the SAGD process was initialized by Wet Electric Heating (WEH) (Yuan et al., 2004). It was observed that the increase in vertical well pair spacing using WEH initialization could improve poor SAGD performance in the model.

Method and / or theory

The reservoir properties used in the simulation model are included in the following section. In addition, vertical well pair spacing in the SAGD simulation model was increased to test as a remediation technology to reduce the negative shale impact on SAGD performance. In that case, the SAGD process was initialized by Wet Electric Heating (WEH). In the simulation model, an increase in vertical well pair spacing using WEH initialization improved poor SAGD performance at early stages of production.

SIMULATION

Table illustrates the reservoir properties used. They were based on the Athabasca deposit.

Parameters used in the model

Initial Reservoir Pressure, P_r	2900 kPa
Initial Reservoir Temperature, T_r	13 °C
Porosity, ϕ	32 %
Vertical Permeability, k_v	1/3 k_h
Horizontal Permeability, k_h	4 D
Initial Water Saturation, S_{wi}	0.14
Initial Oil Saturation, S_{oi}	0.86
Pay Thickness, h	25 m
Length, L	600 m
Width, w	121 m
Depth, D	470 m
Steam Injection Temperature, T_i	263 °C
Maximum injection bottomhole pressure, P_{bhmax}	5000 kPa
Minimum producer bottomhole pressure, P_{bhmin}	3000 kPa

Figure 2 illustrates the steam chamber and SAGD performance in a homogeneous reservoir without shale. The steam chamber developed uniformly in the homogenous environment, as shown in Figure 2.The oil rate had a maximum value around 200 m^3/day, which is reasonable for a SAGD process with these reservoir properties. In another representation, shale layers were randomly located to determine the impact of shale on SAGD performance. In the model, randomly implemented shale layers behave as the shale laminates in the Athabasca area. The reservoir was represented by a 121×1×25 grid, with block sizes of 1m×600m×1m. In the "Shale Case 1", eight shale layers 6 to 7 m in width and 1 m thick were symmetrically located at the top 5 m of the reservoir, as shown in Figure 3, first figure on the left. The steam chamber, figure second from left in this Figure 3, is fairly uniform and is very similar to the one for the no shale case, indicating that the shale had little impact. Figure 3 also compares the SAGD performances in the presence and absence of shale at the top of the reservoir. The shale layers in the top part of the reservoir had an insignificant impact on SAGD performance.

In the "Shale Case2", as shown in Figure 4, there were three layers of shale; two just above the injection well and one on the left side of the reservoir. The steam chamber at the second year of the SAGD process from Figure 4 shows the disturbance in the development of steam chamber due to the shale layers just above the injection well. The shale layers located close to the upper part of injection well had a significant impact on the shape of the developed steam chamber which is confirmed by the SAGD performance difference between the no shale case and Shale Case 2 (Figure 4).

Several simulation cases were performed using different shale locations and showed that shale location could determine the magnitude of impact of shales in the SAGD process.

Remediation Technology

Figure 5 illustrates the well and shale locations for a typical SAGD, where the vertical well pair spacing is 5 m and for a Wet Electrical Heating, WEH, SAGD initiation process where the vertical well pair spacing is 10 m, respectively.

Steam chambers at two different times for Shale Case 2 and for the WEH case are shown in Figure 6. While the Shale Case 2 steam chambers show significant irregular development caused by shale, steam chamber at the beginning of the second year from the WEH case where vertical well pair spacing is 10 m, has little shale impact and it becomes almost regular in shape, at 2.5 years.

Figure 6 also shows a comparison between the SAGD oil rates for these two cases. SAGD initialization with WEH, which has 10 m vertical well pair spacing, can reduce the negative impact of shale on SAGD performance at the early stages of production.

Results and discussion

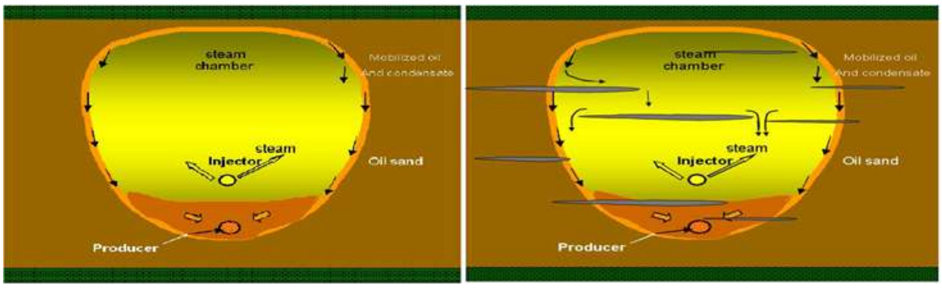

Fig. 1. Vertical cross-section of a reservoir during SAGD and SAGD process with shale barriers

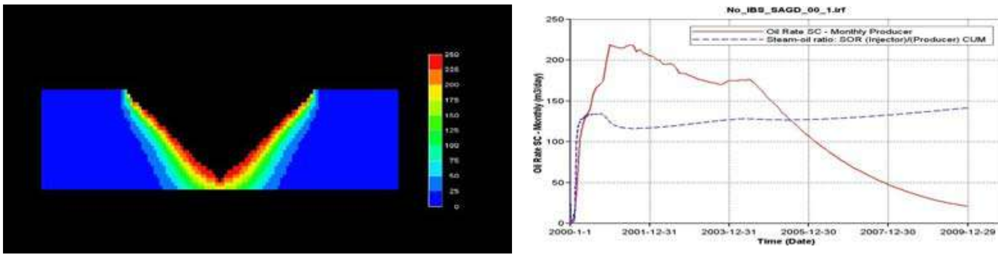

Fig. 2. The steam chamber at the second year and performance for the no shale SAGD case

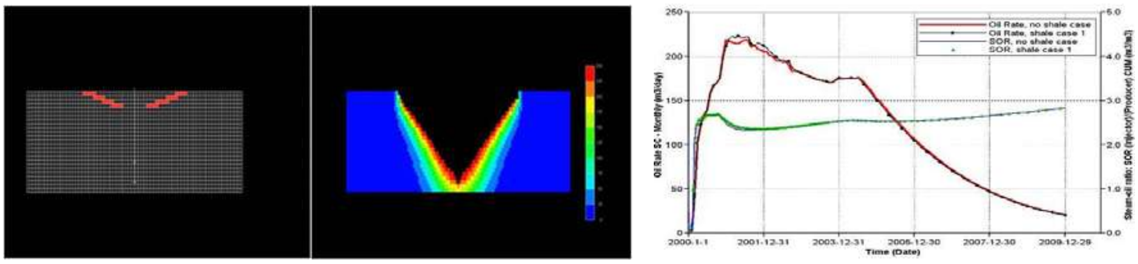

Fig. 3. Shale locations, the steam chamber at the second year and comparison of SAGD Performances between the no shale case and the Shale Case 1

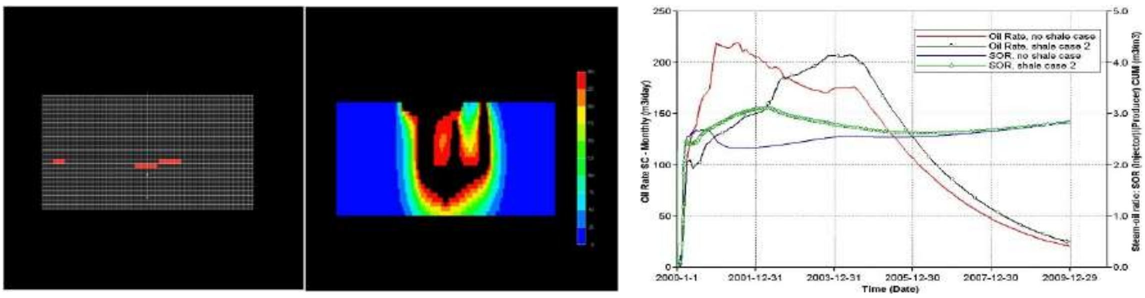

Fig. 4. Shale locations, the steam chamber at the second year and the comparison of SAGD performances between the no shale case and the Shale Case 2

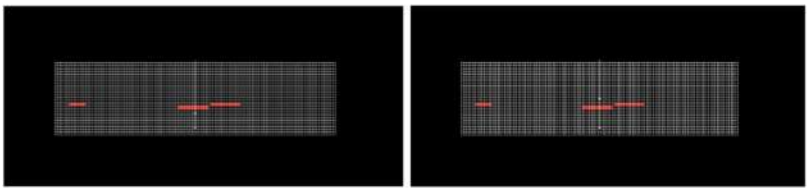

Fig. 5. Well and shale locations in a usual SAGD and WEH process

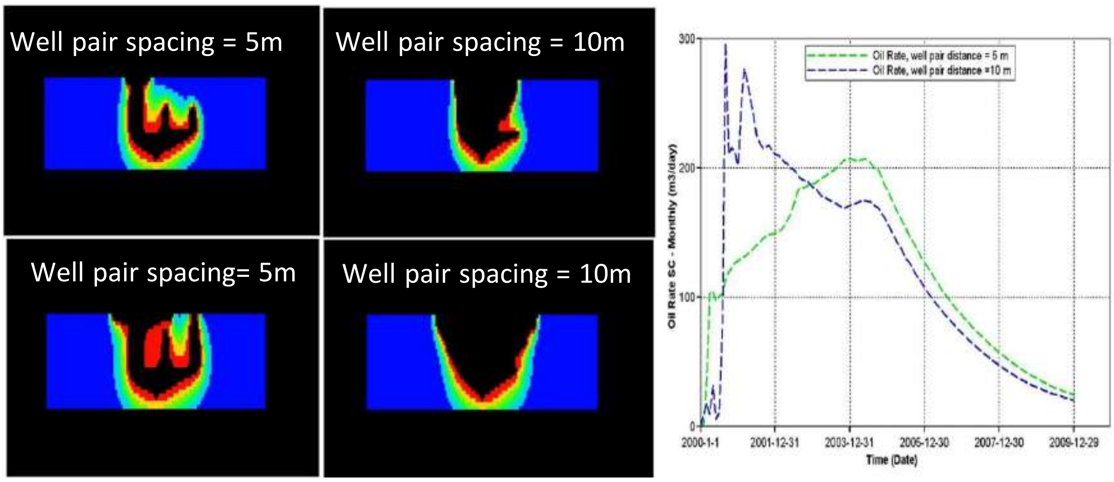

Fig. 6. Comparison of steam chambers and SAGD performance between the Shale Case 2 and WEH case

Conclusion

Shale impact on SAGD performance was evaluated in simulations and the preliminary conclusions from these simulation results are:

1. SAGD performance and steam chamber development can be sensitive to the location and the size of the shale above the injector
2. An increase in vertical well pair spacing, from 5 m to 10 m, using a WEH initialization can reduce the negative impact of shaliness above the injector and can improve SAGD performance at the early stages of production.
3. It is recommended to do further detailed study for varying location, distribution and size of laminated and interbedded shales to have a better understanding of shale impact on the performance and steam chamber development, and to have a better recommendation for vertical well pair spacing to overcome the shaliness negative impact on SAGD performance for the remediation technology

Acknowledgement

The author thanks the AERI/ARC/ Core/Industry Research program for their guidance in the initiation of this research topic. Many thanks are also due to Jian Yang Yuan and Yoshiaki Ito of ARC at that time, for helpful discussions.

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