PS Effect of Reservoir Heterogeneity by Depositional Environment and Its Application to the SAGD Process*

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Search and Discovery Article #42541 (2020)**
Posted June 15, 2020

*Adapted from poster presentation given at AAPG 2019 International Conference and Exhibition, Buenos Aires, Argentina, August 27-30, 2019
 DOI:10.1306/42541Hyundon2020

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Abstract

The Steam-Assisted Gravity Drainage (SAGD) process is the most popular recovery method to develop oil sands reservoirs by injecting steam and producing mobile bitumen using two horizontal wells in western Canada. The SAGD production performance is affected by various reservoir parameters such as permeability, water saturation, porosity and reservoir thickness (Kamath et al., 1993; Shin et al., 2005). The depositional environment of the oil sands reservoir is strongly related to the heterogeneity of the reservoir parameters and thus has substantial impacts on the SAGD performance. This research demonstrates the impact of the heterogeneity of the depositional environment on the SAGD performance through a flow simulation study and applied it for predicting the SAGD production performance.

According to the previous studies, a fining upward deposition environment resulted in the better performance of SAGD than a coarsening upward case because the more permeable path is required for better steam propagation from the injector and mobile bitumen flow to the producer (Shin et al., 2005). The simulation study to quantify the effect of permeability at the various vertical locations shows that the effect of permeability at the top is marginal and the permeability near and below the injection well is most influential on the SAGD performance. This implies that high permeability near the two horizontal wells located at the bottom part of the reservoir is preferable for better SAGD performance. On the early stage of oil sand reservoir development, if there exists not enough geological data for constructing a 3D geological model, the production forecasting simulation can be carried out with an appraisal well-based layer-caked or a homogeneous model; however the layer-caked model has a high uncertainty in its lateral continuity of the impermeable layer, if it exists, and its impact on the performance is very significant. Therefore, a homogeneous model using a proper weighted-average method depending on the vertical location might be more reasonable for production forecasting. The various weighted average methods have been investigated with the reservoir model of the depositional environments which can be found in oil sand reservoirs. The highly bottom weighted-average method brings the closest and most reasonable performance result to the heterogeneous model case. This result also can be used for oil sands potential evaluation using reservoir average parameters.

References Cited

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Shin, H., and M. Polikar, 2005, Optimizing the SAGD Process in Three Major Canadian Oil-Sands Areas: SPE 95754.

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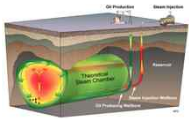
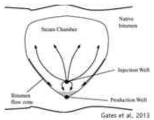
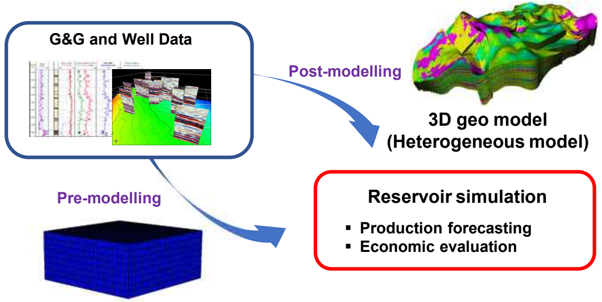
1 Background of the Study

- **Steam-Assisted Gravity Drainage(SAGD) Process**
  - ✓ Two horizontal wells at the bottom of oil sands reservoir: 5 m vertical off
  - ✓ Steam injection at the bottom well → steam chamber development
  - ✓ SAGD performance is critical impacts to reservoir parameters (vertical permeability, thickness, saturation)

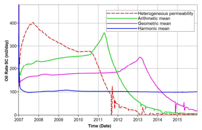



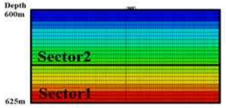
- **Production forecasting by reservoir simulation**
  - ✓ Early stage in development : homogeneous model using cored well information (well base model or layer caked model)
    → simple and quick, but high uncertainty in production forecasting
  - ✓ Post-modelling: 3 D heterogeneous reservoir model based on geostatic model
    → waiting for modelling, but high quality in production forecasting



2 Research Objectives and Methodology

- **Homogeneous model reflecting a degree of heterogeneity**
  - ✓ Large error and uncertainty from averaging reservoir parameters to build a homogeneous model
  - ✓ The vertical location of low permeability zone has a critical impact on production
  - ✓ Require the better averaging method to improve production forecasting in early development stage
- **Sensitivity Analysis of low permeability layer on SAGD productivity**
  - ✓ Identify and quantify the impact of permeability in vertical location
- **Determine the optimal weighted averaging method**





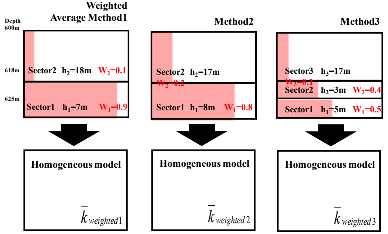
<Sector1>
No of layers: n_1, Weight: w_1
<Sector2>
No of layers: n_2, Weight: w_2

$$\bar{k}_{weighted} = \frac{\sum_{i=1}^{n_1}(k_i \times w_1)_{Sector1} + \sum_{i=1}^{n_2}(k_i \times w_2)_{Sector2}}{\sum_{i=1}^{2} w_i}$$

3 Reservoir Modelling and Simulation

- **2D Numerical simulation model**
  - ✓ Grid size: 1m x 900m x 1m (i x j x k)
  - ✓ Thickness=20m~30m, Perm=0.1~4 Darcy, Porosity 0.28, So = 0.8
  - ✓ Four different averaging methods to define the optimal weighted average methods

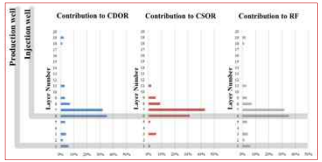
	Heterogeneous models			Homogeneous Permeability (D)			
#	Depositional Environment	Permeability Range(D)	Distribution Type	Arithmetic average	Weighted Average 1	Weighted average 2	Weighted Average 3
1	Fining upward	0.1 - 2	Linear	1.05	1.66	1.53	1.63
2	Fining upward	0.1 - 4	Linear	2.05	3.31	3.03	3.24
3	Fining upward	2 - 4	Linear	3.00	3.65	3.50	3.61
4	Fining upward	0.1 - 2	Exponential	0.65	1.31	1.14	1.26
5	Fining upward	2 - 4	Exponential	2.58	3.27	3.09	3.22
6	Coarsening upward	0.1 - 2	Linear	1.05	0.44	0.58	0.47
7	Coarsening upward	0.1 – 4	Linear	2.05	0.79	1.08	0.91
8	Coarsening upward	2 – 4	Linear	3.00	2.35	2.50	2.39
9	Coarsening upward	4 - 2	Exponential	2.58	2.12	2.21	2.14



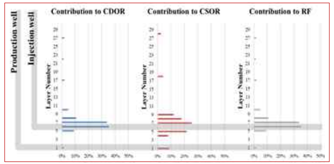
4 Results

- **Sensitivity Analysis**
  - ✓ **Shows a high impact of the permeabilities near injection well**

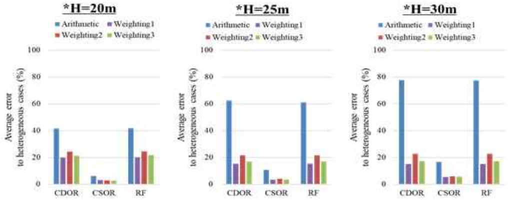
20 m thickness case



30 m thickness case



- **Weighted averaging method**
  - ✓ **Weighted averaging methods has less error than arithmetic average one**



5 Conclusions

- **Sensitivity analysis of permeability impact on vertical location**
  - ✓ Permeability at the bottom part of reservoir is important in the SAGD Process
  - ✓ Higher impact near Injection well permeability distribution
- **Depth weighted permeability averaging method**
  - ✓ Depth weighted averaging methods shows the closer forecasting than arithmetic one
  - ✓ The optimal method is 90% weighted on lower 7m with 10% weighted on above 7m intervals
  - ✓ Fining upward depositional environment is favorable candidate for the SAGD process