

Production from SAGD pads vs. SAGD well pairs: role of conductive heating and infill drilling on ultimate recovery

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Summary

Combined mechanisms and observed production patterns are becoming better understood based on data from maturing SAGD production pads. Evidence is provided from multiple operators indicating that production later in the well life cycle in a particular well pair may be associated with another well pair, another portion of the pad or adjacent pad, and not necessarily from the immediate vicinity of the well pair. The economic reality is that no in-situ operator drills a single SAGD well pair to obtain commercially viable production. Instead, multiple well pairs on contiguous pads provide the benefits of multiple recovery mechanisms resulting in enhanced recovery from oil sands reservoirs. Recovery factors on the order of 50% to 70% are realized by longer term production on a pad basis due to the combined production mechanisms of steam chamber amalgamation, conductive heating with gas push, infill wells and an effective wind-down strategy.

Introduction

Analysis of post-steam cores, temperature observation wells and Residual Saturation Tool (RST) logs obtained from the Alberta Energy Regulator (AER) website illustrate that SAGD bitumen production, results from both convective heating (within the expanding steam chamber) and conductive heating (from above the steam chamber). Vertical permeability baffles and barriers created by Inclined Heterolithic Stratification (IHS); (Figure 1) may stop or create long term delays in steam chamber rise due to interbedded mudstones within the IHS. Steam has a tendency to go laterally instead of vertically where mudstones are encountered. The common assumption is that if steam does not get up into the bitumen, how can bitumen flow down?

Theory and/or Method

Steam rise may have less impact on overall production than originally thought, due to the contribution of mobilized bitumen from conductively heated portions of these reservoirs. After several years of heating on contiguous well pads with 16+ SAGD well pairs, combined heat flow from conductive heating from amalgamated steam chambers enables significant drainage over an area of at least 800m X 800m. Relatively continuous vertical permeability barriers are seldom more than 200m in length, allowing significant amounts of conductively heated bitumen to be produced. Note that the heel portion of well pairs, including the build section can also be produced and drained effectively due to conductive heating and amalgamating steam chambers.

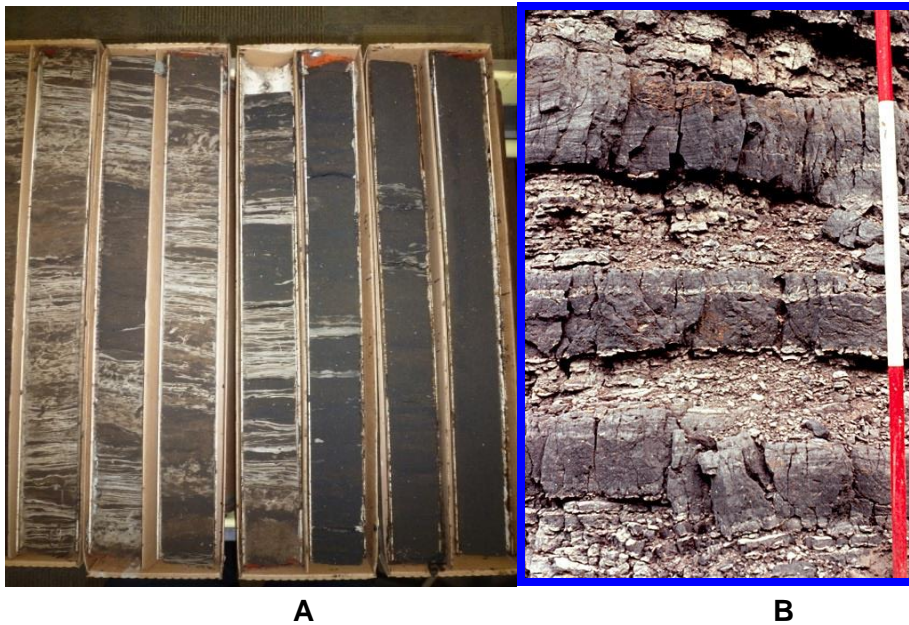


Figure 1: Interbedded mudstones (grey) and sands (black) of IHS, McMurray Formation oil sands deposits in core (A) and outcrop (B).

The theory proposed in this paper is that recovery from bitumen trapped above or within IHS and above the steam chamber is enabled by non-condensable gas push combined with gravity where conductively heated bitumen exceeding 80^o C flows along 3-dimensional interconnected down-slope pathways created by erosional events, re-activation, rotation and translation of the point bar successions. Amalgamation of expanding steam chambers multiple well pairs provide extensive heat distribution and drive energy to maximize conductively heated production. Recovery factors on the order of 50% to 70% are realized by longer term production on a pad basis due to the combined production mechanisms of steam chamber amalgamation, conductive heating with gas push and infill wells.

Discussion

Optimistic assumptions for recovery and production must also be balanced with 3-dimensional knowledge about the reservoir architecture and well pair placement with respect to reservoir heterogeneity. Assuming traditional low pressure SAGD operations, reservoir heterogeneity can have profound effects on production performance. The presence of IHS commonly creates permeability challenges that can result in variations in steam-chamber height along the well pair, inconsistent sub-cool conditions, variable production performance, and in some instances, flashing steam to the producer resulting in liner damage (Strobl, 2013).

Production performance is particularly affected in SAGD operations where IHS-dominated intervals are encountered at the base of the reservoir. The presence of mud-dominated IHS can create a laterally extensive permeability barrier between the injector and producer wells preventing communication and/or creating large pressure differentials. Efficient production in SAGD follows a codependent cycle of displacement of bitumen to the underlying producer, allowing continued steam injection; and the development of a “steam in” and “bitumen out” process.

New technologies are evolving to help mitigate some of the effects of reservoir heterogeneity on communication between the producer and injector wells and the associated production performance. New start-up methods including high pressure steam stimulation, cold water dilation and/or solvent soak are currently being tested by operators and documented in AER annual reports, which offer a basis for potential commercial success even in more heterogeneous oil sands reservoirs. Equalizers or inflow control devices may reduce the effects of steam short-circuiting, resulting in increased production rates in reservoirs of variable thickness and quality. These methods may become the new “norm” for SAGD operations providing higher recovery factors and continued reduction of steam-oil-ratios as our industry evolves.

Conclusions

In reservoirs with good communication between injector and producer wells and where steam chambers amalgamate within contiguous pads with multiple well pairs, recovery factors on the order of 50 to 70% is proven. With new start-up procedures involving geomechanical methods, advances in drilling technologies, better pump designs and tools for mitigating the effects of sub-cool, SAGD or its successor will continue to provide competitive commercial production rates with continued advances in reducing greenhouse gas emissions along with reduction in water use.

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