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Detecting and characterizing a high permeability, thin micro-layer at the bottom of a heavy oil formation

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Abstract

The development of the novel **i**n-**s**itu **c**ombustion (ISC) process, Toe-to-Heel Air Injection (THAI) and its field testing in 6 heavy oil reservoirs, worldwide, brought a new perspective on ISC use for heavy oil recovery. It made us aware of the fact that ISC can be used both for oil recovery and in-situ oil upgrading. ISC, in general, has better energy efficiency and less environment pollution than steam-injection methods, and it attracted more interest in the last years; THAI even so, it is less polluting that classic ISC as it leaves a series of pollutants in the reservoirs. Additionally, THAI produces hydrogen contained in the recovered gases, and there are preoccupations to for the further use of the hydrogen, therefore for THAI to have the hydrogen as a by-product. A schematic of the THAI process is provided in Figure 1.

Analysis of four old ISC field projects revealed that upgrading was related to preliminary generation of oriented heterogeneity by man-made fracturing (for instance horizontal fracturing performed close to the bottom of pay), followed by intensive heating using cycling steam stimulation (CSS) or other means; this created a possibility for inadvertently operating a quasi-THAI process. Also, there was upgrading in case the ISC was carried out after the **c**old **h**eavy **o**il **p**roduction with **s**and (CHOPS) followed by very intensive CSS pre-heating, but in this case people failed to find any plausible explanations of upgrading, given the fact that the anatomy of the "wormholes" was unknown.

Very recent investigations showed that it is possible that even without those preparatory operations (fracturing, preheating, etc) an in-situ upgrading can exist. It is strongly believed that a permeability distribution (with highest permeability near the bottom of formation) favored a pseudo-THAI ISC. This occurred in the following classic conventional dry ISC projects: West Newport Field (WNF), California, USA, Morichal Field, Venezuela, Tia Juana Field, Venezuela and Jurassic Badaowan, H1 Block, Xinjiang, China. It is to be underlined that except WNF project, all these projects were conducted in heavy oil reservoirs with temperature higher than 60 ^{0}C. Therefore, with two conditions met (unique permeability distribution and reservoir temperature above 60 ^{0}C) there is a possibility to apply ISC for both heavy oil recovery and in-situ oil upgrading and hydrogen production.

Given the importance of identifying and characterizing a high permeability, thin micro-layer at the bottom of a heavy oil formation, both a theoretical investigation and a technological one has been considered in this project.

The theoretical investigation is related to the evaluation of the depositional system which favors an increase of permeability in a downward direction, otherwise expressed a coarsening in a downward direction. The signs of regional geology elements indicated such a trend are investigated.

As far as the detection of a high permeability, thin micro-layer at the bottom of a heavy oil formation by using the logs is concerned, the use of resistivity logs is discussed, trying to use the correlation between connate water saturation and permeability, when possible. Tangentially, other logs are discussed.

Another means discussed is the use of thermal surveillance, i.e. thermal profile during a temporary water injection to determine if there are any anomalies throwing a light on this subject; a cooling of a certain interval can be detected.

Finally, if the ISC process is to be applied after a commercial waterflood, then the existence of consecutive cementation of perforation starting near the bottom and going up, would be an indication of highest permeability near the bottom of oil formation.

Besides those 4 main procedures discussed in detail, other possible ones are discussed on-the-fly and their feasibility is evaluated.

In this project, a difference is made between the cases where many separate layers compose the heavy oil formation and when no such separation (per layers) exists but still a clear, pronounced increase of permeability in a downward direction exists.

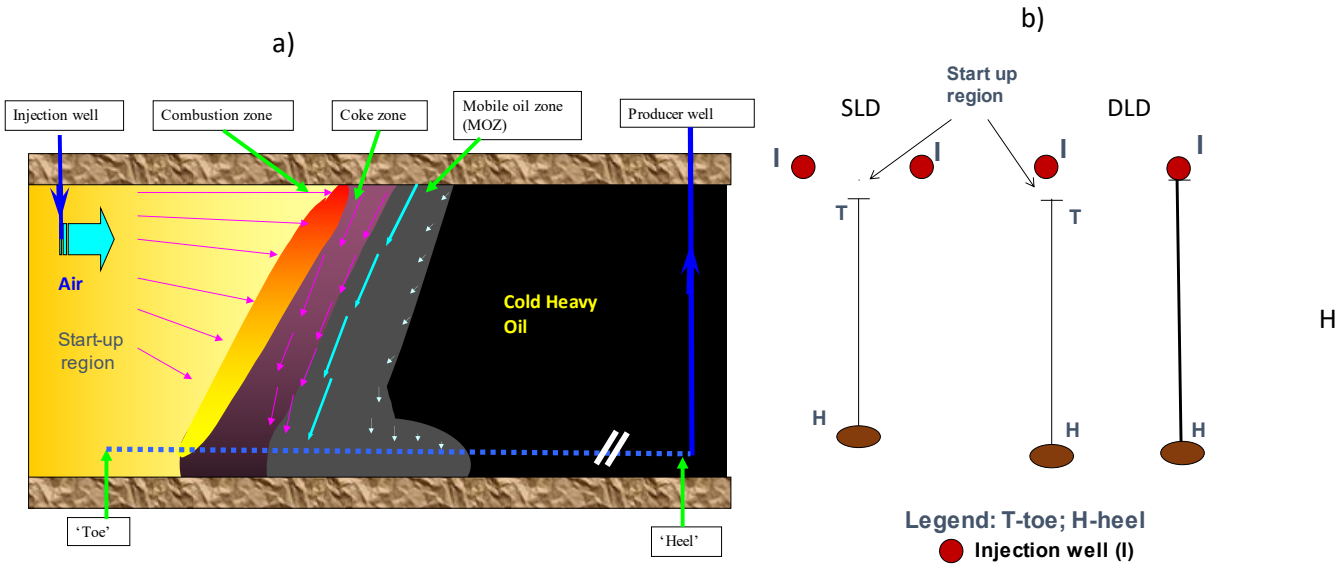

Figure 1: Schematics of THAI and its generalization for the case of ZERO start-up region (or without a start-up region). a) Schematics in vertical section ; b) Bird-eye view (view from above). DLD=direct line drive and SLD= staggered line drive

Explicative note for Figure 1: Air injection well is vertical and perforated in the upper half of pay section, while the production well is horizontal, with its horizontal section located near the bottom of layer and having its toe close to the shoe of vertical injector (more details on THAI process from the website: www.insitucombustion.ca).

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