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Application of Time Lapse Geochemistry to better understand the barriers to fluid flow in a reservoir in Naharkatiya oilfield, Upper Assam

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Abstract

The paper describes the application of time lapse geochemistry to a reservoir in Naharkatiya oilfield in Upper Assam, India to understand the barriers to fluid flow in different parts of the reservoir under dynamic conditions. Oils from different parts of a reservoir having fluid flow barrier between them, have subtle difference in composition which can be identified through fingerprinting of oils using Gas Chromatograph (GC).

Naharkatiya oilfield is a mature oilfield selected for implementation of carbon dioxide (CO_2) enhanced oil recovery (EOR). Dynamic simulation study of the reservoir has identified two inverted five spot patterns for implementation of CO_2 EOR. Well head crude oil samples from the five producing wells in the reservoir were collected in 2017 and 2019 (time lapse) and their detailed fingerprinting was carried out using a GC.

The study showed that there is poor connectivity between a particular well (Well F), that is part of the both the EOR patterns, and other nearby wells while there is good connectivity among other four wells that were studied. The knowledge of the fluid flow barrier in the reservoir has significant implication to the successful implementation of EOR in the reservoir.

Introduction

A petroleum reservoir is defined as a subsurface rock formation containing one or more individual and separate natural accumulations of moveable petroleum that is confined by impermeable rock and is characterized by a single-pressure system (https://www.spe.org). A reservoir may be compartmentalized vertically, due to the presence of continuous low permeability shales or laterally, by structural features like faults. In a compartmentalized reservoir, fluids do not flow freely from one part to another over production time scales (Muggeridge et al., 2008). During the reservoir filling process, the fluid composition of the accumulating hydrocarbons may not be uniform as the hydrocarbons from different source rocks, or from the same source rock that is maturing over time may migrate in to the reservoir. Thus, the composition of hydrocarbons in different parts of the reservoir may not be homogenous. Mixing of fluids in different part of the reservoir is a slow process. Lateral compositional gradients may take several million years to homogenize, however, vertical compositional gradients may homogenize in few thousand to hundreds of thousands of years (Muggeridge et al., 2008). Under dynamic conditions i.e. once the reservoir is on production, the compositional gradients may homogenize in few years. Thus, compositional heterogeneities, persisting in the oils from two nearby wells after production for few years, indicate a fluid flow barrier between the two wells. In a mature field, this information is vital for building a dynamic simulation model for enhanced oil recovery pilot design.

Time-lapse geochemistry is an approach utilizing geochemical techniques and methods to identify and monitor subtle compositional changes in produced fluid samples collected over a period of time that could signal and/or explain significant changes in dynamic reservoir performance and production. The results of time-lapse geochemistry studies provide verification and/or improvement of static and dynamic reservoir models as well as predictive capabilities. The approach of time-lapse geochemistry requires availability of representative fluid samples (oil, gas, and water) collected from the same reservoir over a period of time during appraisal, development and production (Chuparova et al., 2010). Gas chromatographic (GC) fingerprinting of oils is a geochemical analytical tool that can identify subtle compositional differences in oils collected from different wells in a reservoir (Kaufman et al., 2002; Milkov et al., 2007). Geochemical analysis of oil using a GC does not replace the more traditional geological and engineering approaches to reservoir description but should be considered as an additional tool. The main benefit of geochemical analysis is that it is inexpensive and can be done quickly.

Dynamic simulation study was carried out in an Oligocene (Barail 3rd Sand) reservoir in Naharkatiya oilfield of Oil India Limited in Upper Assam, India in order to design a pilot for carbon dioxide (CO_2) enhanced oil recovery (EOR). Two inverted five spot patterns were identified during the EOR pilot design of the above reservoir (Fig. 1). Wells A to F and H are part of the two patterns. The first well in the two patterns (Well A) came on production in 1969 while the last well (Well H) came on production in 2014. During this study, oil samples were collected from Wells C, D, F, H and I that were on production in 2017 and subsequently after a time lapse of two years, in 2019 and gas chromatographic fingerprinting of these oils was carried out. This paper presents the application of the technique of gas chromatographic fingerprinting on the oils of this reservoir to understand the fluid flow barriers in the reservoir which can help in building a better dynamic simulation model for EOR pilot design.

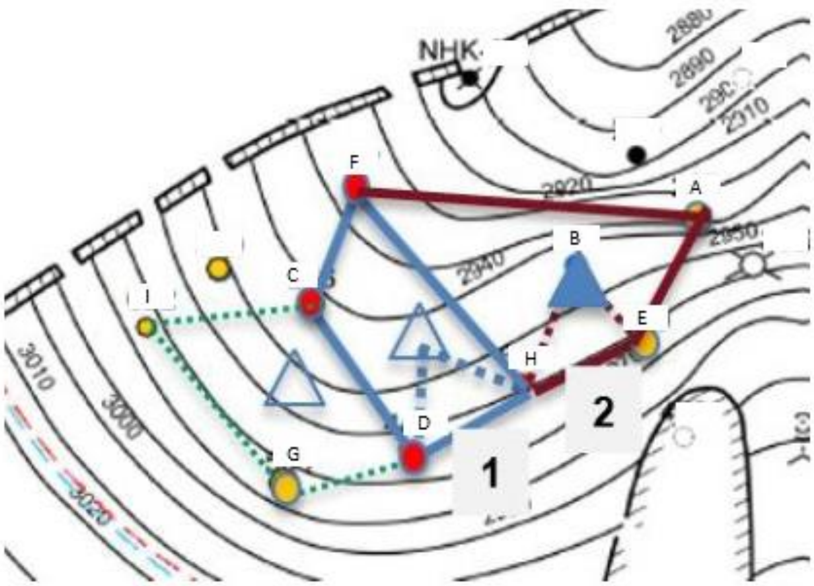

Figure 1: Map of the Study Area showing two patterns identified for CO_2 EOR Pilot

Methodology

Well head crude oil samples were collected from Wells C, D, F, H and I that were on production in 2017 and subsequently after a time lapse of two years, in 2019. Detailed fingerprinting of oil was carried out using a gas chromatograph (GC). A capillary column of length 60m, internal diameter 0.25mm and having a 100% non polar stationary phase of film thickness of 0.25µ was used. The injector and detector of GC were maintained at 300°C and 310°C respectively. Column oven program was as follows: 40°C (10 min) - 8°C/min - 310°C (10 min) with a total run time of 53.75 min. The gas chromatograms of all the oils were examined in great detail to look for subtle differences in composition. A large number of GC peaks were selected and their ratios were plotted in a star diagram to discriminate the oils.

Results and Discussion

Wells F and H

During this study, each pair of oil samples, collected from adjacent wells in the year 2017 and 2019, has been examined for the compositional difference. Well F started producing in August, 2010 whereas Well H came on production in April, 2014. The distance between the two wells is 668m. Figure 2a shows the star plot for Well F and Well H for the crude oil samples collected in 2017. It can be seen that the two oils are compositionally distinct. The star plot for the oils from the same wells collected in 2019 is shown in Figure 2b. It is observed that the compositional difference between the oils is now substantially reduced.

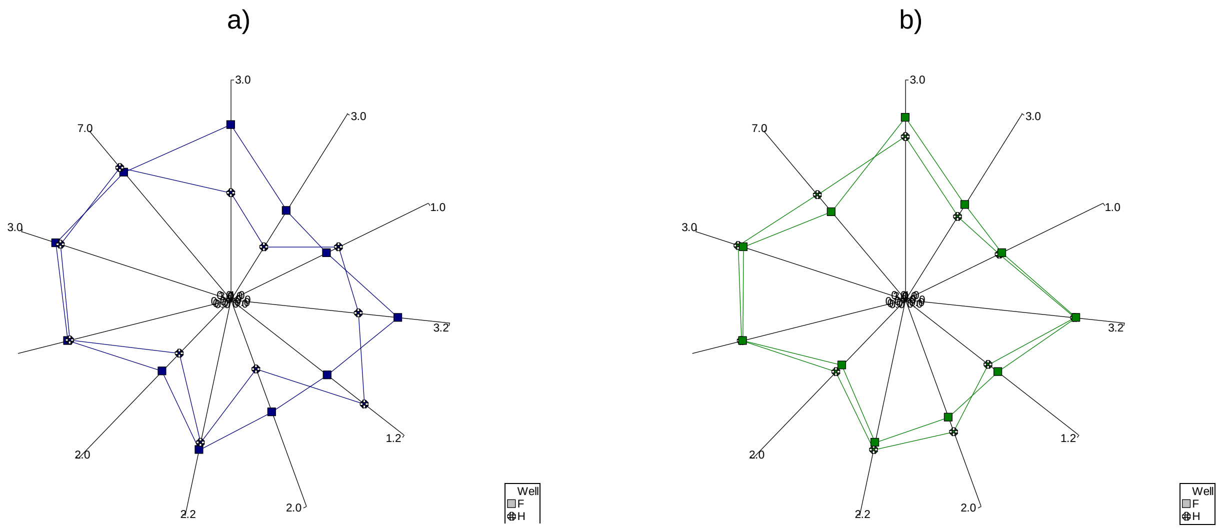

Figure 2: Star plot of crude oils collected from wells F and H in a) 2017 and b) 2019

This implies that the period between 2014, when Well H came on production and 2017, when the oil samples were collected, was not sufficient for the oil near Well F oil to reach Well H. However, by 2019, there was sufficient oil movement between Well F and Well H so that the two oils became similar. This could be due to relatively poorer connectivity between the two wells, and therefore, it took some time for the two oils to become similar in composition.

Wells D and H

Well D has been on production since August, 1990. The distance between Well D and Well H is 433m. The composition of the oil samples from Wells D and H, collected in 2017, is nearly identical (Fig. 3a). This implies that the time duration between 2014, when Well H came on production and 2017, when the oil samples were collected, was more than sufficient for the oil near Well D to reach Well H. Thus, there is good connectivity between wells D and H. However, it is observed that, in 2019, the composition of Well H oil became dissimilar to Well D oil (Fig. 3b). As observed earlier, the composition of Well H oil became similar to Well F oil in 2019 even though the two oils (from Wells F and H) were compositionally distinct in 2017. This implies that, initially, the produced oil from Well H was moving in from the direction of Well D (due to better connectivity between Wells D and H when compared to the connectivity between Wells F and H) and subsequently, Well H started producing oil moving in from the direction of Well F. The oil production rate of Well H remained stable between 30-40 KLPD during January 2017 to January 2019. However, the oil production from Well D sharply declined from 61 KLPD to 11 KLPD during this period. This could be due to the fact that initially the oil produced from Well H was moving in from the direction of Well D. However, as the pool around Well D depleted, more and more oil from the direction of Well F started coming in. Thus, the production from Well H remained stable despite fall in production in Well D.

a) b)

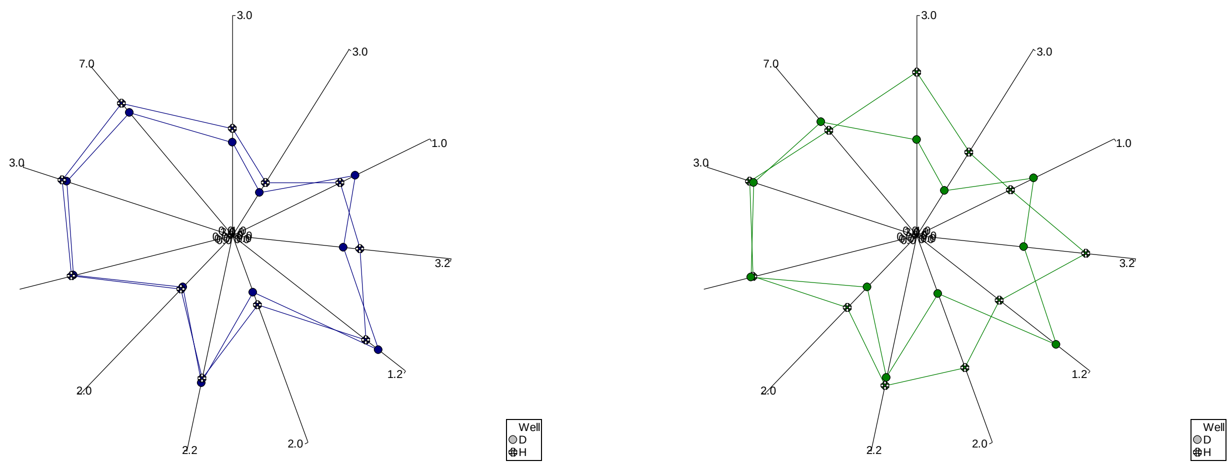

Figure 3: Star plot of crude oils collected from wells D and H in a) 2017 and b) 2019

Distribution of permeability among Wells D, F and H

It can be seen from the permeability distribution between Wells F and H that there is low permeability area around Well F resulting in poor connectivity between the two wells (Fig. 4a). On the other hand, there is better permeability distribution between Wells D and H (Fig. 4b). Thus, the fluid flow between Wells D and H is more efficient compared to fluid flow between Wells F and H. Therefore, the permeability distribution supports the observation that initially, Well H oil is similar to Well D oil as the connectivity between the two wells is better. However, with time as the oil volume around Well D declines resulting in lower production rate from this well (Well D) and the Well H starts receiving oil from the direction of Well F due to drawdown and therefore, becomes compositionally similar to Well F oil.

a) b)

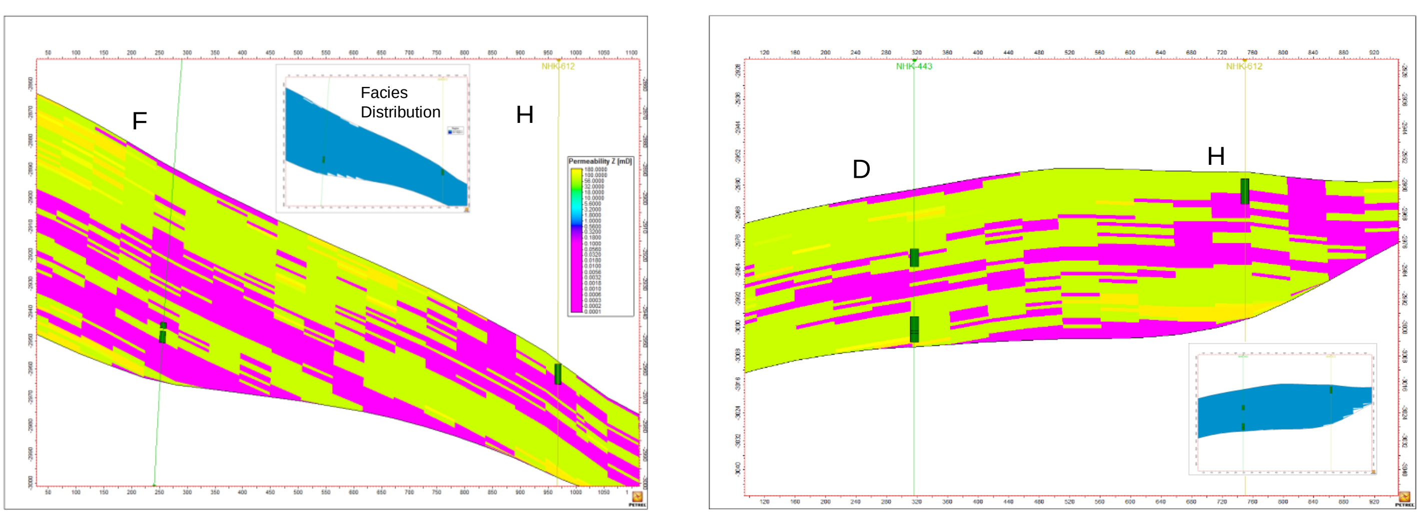

Figure 4: Permeability distribution between a) Wells F and H and b) Wells D and H

Wells C and F

The distance between Wells C and F is 481m. Well C has been on production since December, 1973 and Well F has been on production since August, 2010. The production of Well C has declined from 82 KLPD to 33KLPD between February, 2017 and February, 2019 where the production from Well F has remained more or less stable between 44 and 55 KLPD between January, 2017 and January, 2019.

The composition of the two oils has been different in 2017 as well as in 2019 (starplot not shown here). Had there been good connectivity between the two wells, their composition should have been similar after nine years of production. Considering the production data and the compositional data, it can be concluded that the two wells are poorly connected.

From the above discussion, it can be concluded that there is a permeability barrier around Well F. Since Well F is part of the inverted five-spot pattern for CO_2 EOR Pilot, it is likely that during CO_2 injection in any of the injectors in Patterns 1 or 2, the production from Well F will be less compared to other producers.

Conclusions

In this study, the technique of time lapse geochemistry that involves gas chromatographic fingerprinting of oils collected from the same wells in a reservoir at different times and identification of subtle compositional differences in these oils has been applied. It was concluded that there is a permeability barrier around Well F, which is a part of both the inverted five-spot patterns identified for implementation CO_2 EOR in the reservoir in Nahakatiya oilfield in Upper Assam. The results of the study have helped in building a better dynamic simulation model required for EOR pilot design of the reservoir.

Thus, Gas chromatographic fingerprinting oils from a reservoir, collected at different times (time lapse geochemistry) can help in identifying fluid flow barriers in a reservoir.
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