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Investigation of the Cause of Declining Oil Production of Haripur Oil Field in NE Bangladesh using Streamline Simulation

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***Abstract*— Haripur oil field is the only commercial oil field discovered in Bangladesh. But the cessation of the production with a very low primary recovery of the country's single promising commercial oil field was unexpected and discouraging. The objective of this research is to find out the possible reasons behind this premature abandonment of oil production using streamline based flow simulation. Schlumberger Eclipse FrontSim streamline simulator has been used for developing streamline based flow simulation model of entire production period integrating structural model, petro-physical properties, PVT and production data. Generated streamline simulation model has been thoroughly analyzed to track the changes of the properties of the fluid system within the reservoir. This made a striking discovery that steep pressure drop during production caused the liberation of solution gas from oil and created gas segregated areas in oil horizon. It made oil more viscous and resistance to flow. Furthermore, gas segregated areas created oil flow barrier. Due to these unexpected consequences, the oil flow rate decreased sharply and the production was abandoned prematurely.**

***Keywords*— Haripur oil field, Streamline simulation, Eclipse FrontSim streamline simulator, petro-physical properties, PVT**

I. INTRODUCTION

Haripur oil field is located about 230 km North-East of Dhaka and 18 km from Sylhet town. It was in production from January 1987 to July 1994 from single well SY-7 and produced only 0.56 MMSTB (Million Stock Tank Barrel) oil. Recent investigation and study have revealed that approximately 31 MMSTB Oil is remaining in that formation as validated by the reservoir performance based study i.e. oil production rate and tube head pressure history matching (Islam, Woobaidullah, & Imam, 2015; RPS Energy, 2009). The primary recovery is less than 2 percent of the STOIIP (Stock Tank Oil Initially In Place) that is exceptionally low. Streamline based flow simulation has been used to decipher the cause of this premature abandonment of oil production of Haripur oil field.

Streamline-based flow simulation has made significant advances in the past 10 years. It is now accepted as an effective and complementary technology to more traditional flow modeling approaches such as finite differences (Thiele, 2003). Streamline simulators approximate 3D fluid flow calculations by a sum of 1D calculations along streamlines (Vargas-Guzmán, Al-Gaoud, Datta-Gupta, Jiménez, & Oyeriende, 2009) after solving pressure equation on an underlying grid as in the same method as a conventional simulation. Quantitative flow visualization, faster computation, inclusion of gravity, 3D effects, multiphase flows are some of the advantages of streamline simulation. This state of the art simulation technology has been used to model and track the dynamic variation of the fluid system within the reservoir of Haripur oil field to find out the cause of its premature abandonment.

II. GEOLOGY AND FILED OVERVIEW

Haripur Oil Field also known as Sylhet Field is located in the Surma Basin, north-eastern extension of Bengal Basin. The Surma Basin, a sub-basin of the Bengal Basin in northeastern Bangladesh, was structurally developed by the contemporaneous interaction of the uplift of the Shillong Massif to the north and the western progradation of the mobile Indo-Burman fold belt (Rahman & McCann, 2011; Hiller & Elahi, 1984). It is the most prolific petroleum province in Bangladesh. Sediments were deposited mainly in open marine, deltaic-shallow marine and continental fluvial environments and composed of primarily sandstone, siltstone and shale (Imam & Shaw, 1987; Rahman & McCann, 2011). These sediments were subjected to the later phases of the Himalayan/ Arakan Orogeny, resulting in the formation of the relatively gentle folding of the frontal folded belt (RPS Energy, 2009). These structures form the traps of hydrocarbon of this area.

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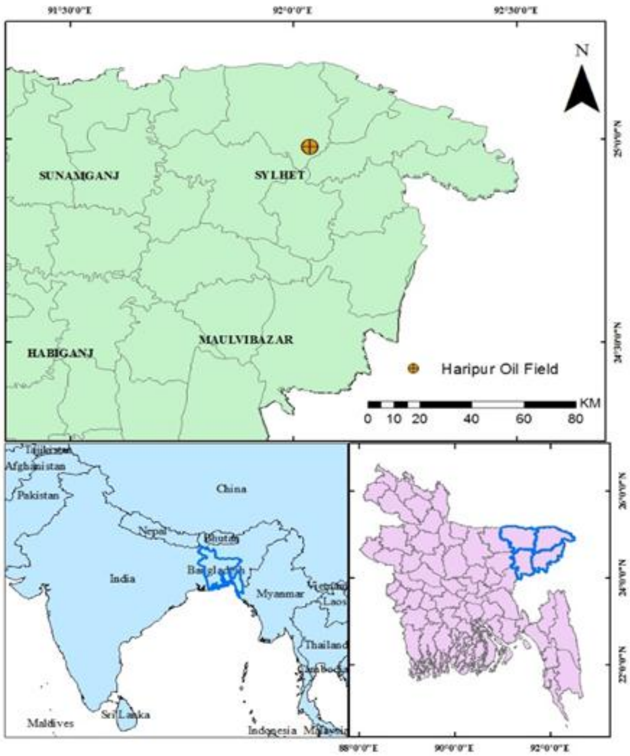

Figure 1 Location map of Haripur Oil Field

Haripur Structure is a compressional anticlinal type similar to the most of the gas fields of Bangladesh. It is an elongate, bow shape anticline trending northeast southwest with a simple four-way dip closure. The structure is 13 kilometer long and 3 kilometer wide. This anticline is slightly asymmetric and influenced by several large faults. It started to form in Miocene period. It lies on the north-eastern fringes of the Surma basin along a trend known as the Jalalabad–Sylhet–Dupatila Anticlinorium. Dip of the Sylhet closure is quite steep, estimated to be about 15 degrees. This structure was first delineated by Pakistan Petroleum Limited (PPL) after recording single fold seismic. Subsequently, well SY-1 well was drilled in 1955 and discovered the first commercial gas accumulation in Bangladesh. Later five more development wells named SY-2 to 6 were drilled. Well no SY-7 was drilled in 1986 as a gas development well but turned out to be the first oil discovery well in Bangladesh. Oil horizon was encountered deeper than gas zones at depth from 2020 to 2033 meter.

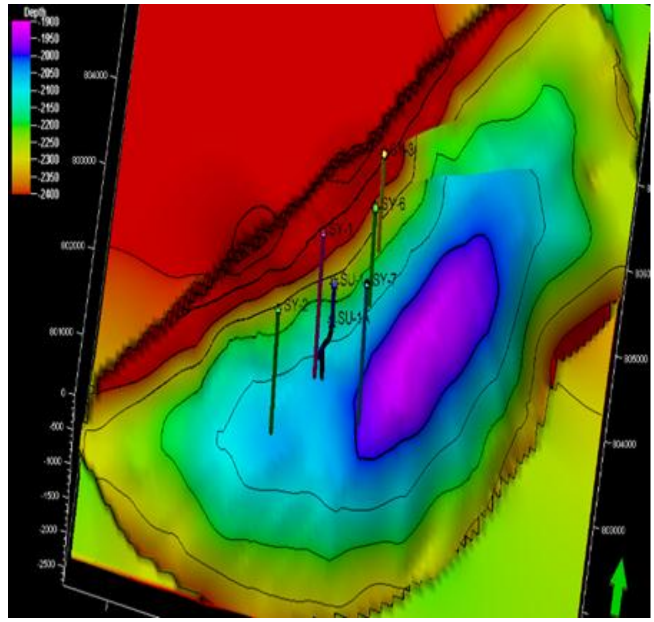

Figure 2: Position of wells drilled in Haripur Structure from the top of the oil horizon (upper Bhuban Formation)

III. Methodology

Streamline simulation model of Haripur oil field has been developed for this investigation. First, a representative reservoir model has been created consisting of structural, petro-physical and fluid model. Geological, geophysical (seismic), well log, fluid (compositional and PVT) data have been used. Well completion and production data have been used to make well completion design and development strategies. Finally, streamline simulation models were developed integrating all of these models using simulator software. The data required for developing streamline simulation model of Haripur oil field were delivered by Petrobangla in both digital and hard copy formats. Schlumberger Petrel software platform has been used for all kinds of modelling and visualization and Eclipse FrontSim Streamline Simulator has been used for simulation. FrontSim is a three-phase, three dimensional black-oil reservoir simulator where the solution mechanism is based on streamline concept (FrontSim Technical Description, 2010). It is based on the IMPES (Implicit Pressure Explicit Saturation) formulation as other finite difference simulators, with the primary difference being that fluid transport or saturation movement is solved along one dimensional streamline space (FrontSim User Guide, 2010).

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Structural model consists of total 74 layers containing upper gas and lower oil bearing horizons of Bokalbil and Upper Bhuban Formation. Wireline log data of every well were used to fill grid cells with petro-physical properties. These properties are porosity, permeability and NTG (Net to Gross Ratio). Well log data were provided in LAS (Log ASCII Standard) format with ".las" extension. Integrating structural model and petrophysical model, representative reservoir geomodel of Haripur Oil Field were created that contains structural model with grid cells filled with petro-physical properties. Fluid models that describe the characteristics of fluid present in the reservoir were developed using PVT data and fluid compositional data. Well completion data were used to create well completion design. Finally, simulation parameters are set in Eclipse FrontSim streamline simulator software to perform simulation. Generated stream simulation models are analyzed for our investigation.

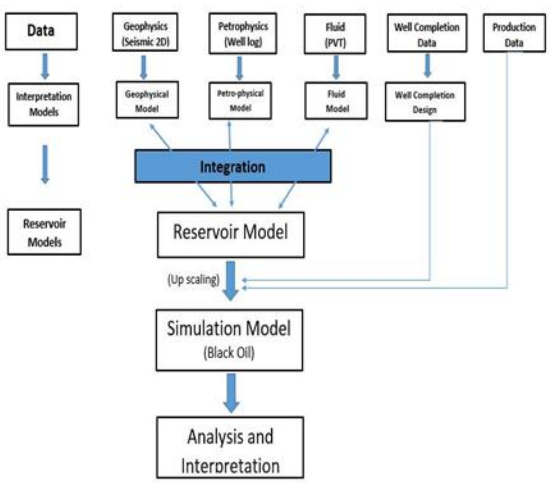


Figure 3: Streamline Simulation Workflow

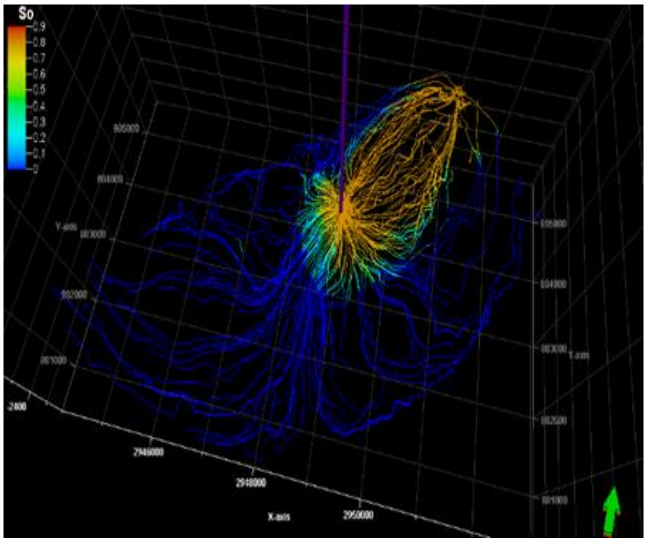
IV. Result And Discussion

Streamline simulation of entire production period (1987-1994) has been performed for this investigation. Streamline generates flow rate, fractional flow rate, saturation attributes providing a better understanding of the reservoir performance inside the porous permeable formation (Batycky, Blunt, & Thiele, 1997).

These attributes are very useful in characterizing the fluid system of a reservoir and its temporal variation. These dynamic variations of the oil and gas saturation have been analyzed for this investigation.

Analyzing temporal variation of streamline simulation model oil saturation of Haripur Oil Field provides the first clue. Oil saturation did not change much with production (Figure 4). Oil saturation ranges from 0.7 to 0.8 in the oil zone on both early and late production stage. Increasing the number of streamlines in late production periods (Figure 4b) indicates the increasing of connectivity within the reservoir. This provides further validation of the previous investigations (RPS Energy, 2009; Islam, Woobaidullah, & Imam, 2015) that much of the oil is still in the formation.

In spite of having saturated in oil, the reservoir pressure was falling abruptly. Figure 5 shows the decline of tube head pressure (THP) of well SY-7 with time. Initially, in 1988 when production started, the THP was more than 700 psi. It gradually declined and went below 200 psi in 1994. As a result, the production was abandoned after producing



(a)

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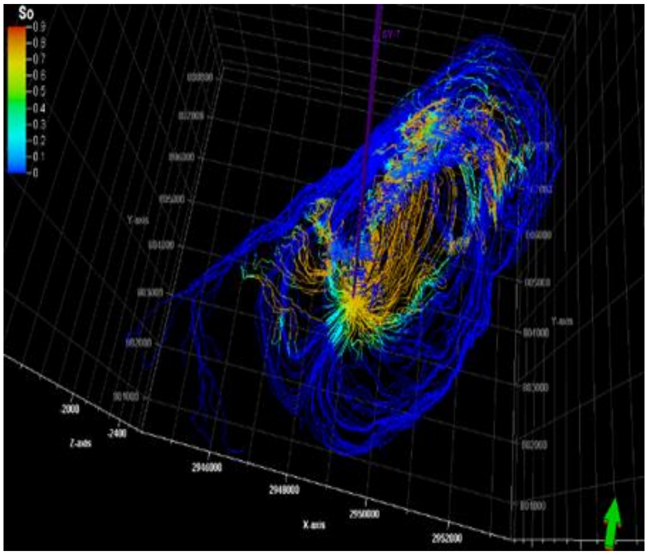


(b)

Figure 4: (a) Oil saturation at the beginning of the production period on January 1988; (b) end of the production period on July 1994

0.56 MMSTB oil in cumulative. Therefore, it can be inferred that the condition of the fluid system might change greatly from its initial causing the decline of flow rate and tube head pressure. On the other hand, gas production rate showed different trend to the corresponding oil production rate. Figure 6 shows oil and gas production rate of well SY-7 with time.

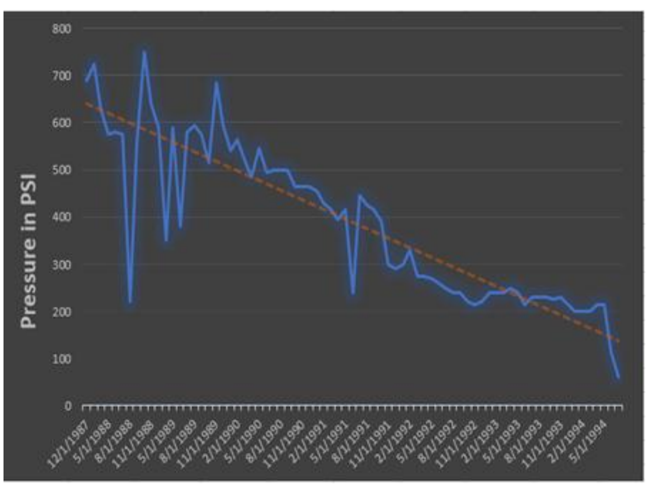


Figure 5: Tube head pressure (THP) of well SY-7 in psi

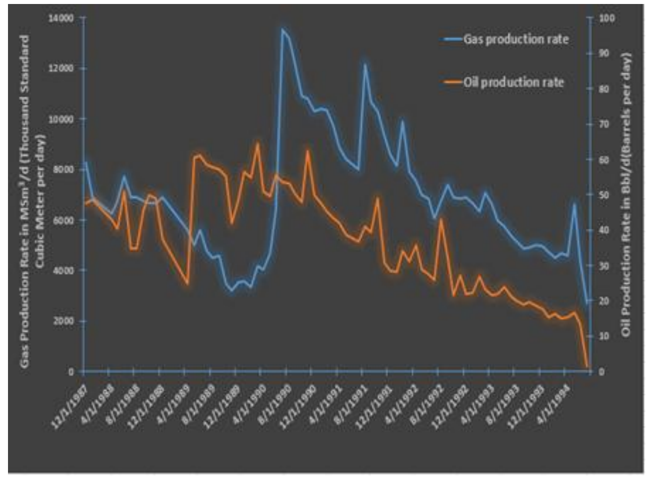
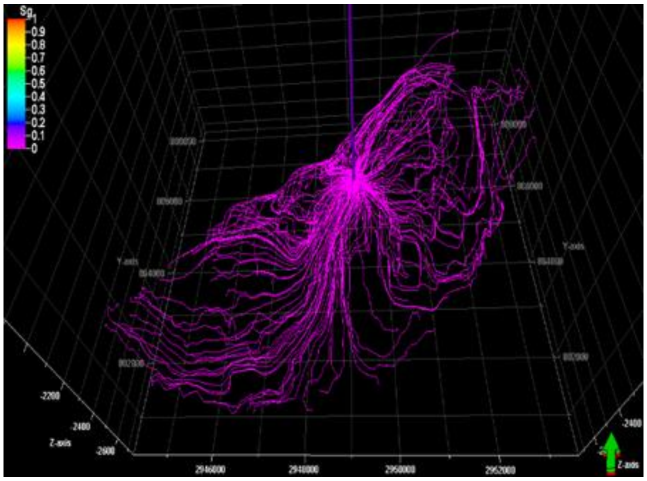
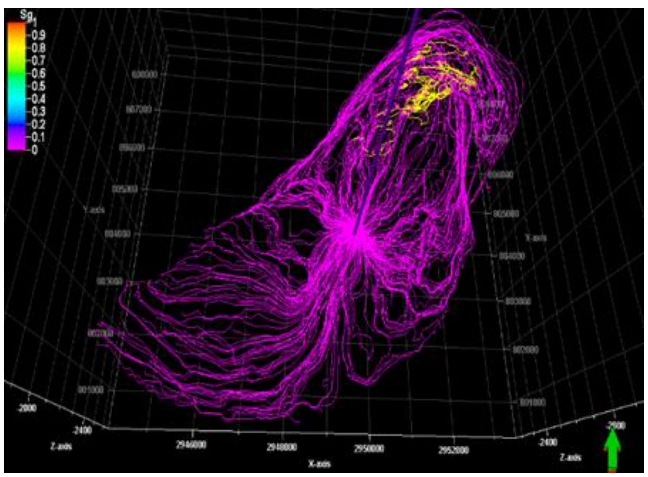


Figure 6: Oil and gas production rate; bbl/d (Barrels per day) for oil and MSm^3 (Million Standard Cubic Meter) for gas

Oil production rate shows decreasing trend with time. But the gas production rate showed decreasing trend initially, followed by steep increasing and then gradually in decreasing trend. Generally, when oil from the reservoir move upward thorough the well, the pressure reduction caused dissolved gas to come out form the solution. This gas production rate generally follows the oil production trend as it come from the oil. But this increasing trend indicates that the excess gas was coming from other sources. Again, this subtle discrepancy indicates that the condition of the fluid system within the reservoir had changed from its initial condition. Gas saturation attributes of streamline simulation model can delineate the gas saturated zones and its temporal variations. Gas saturation has been analyzed to find out any presence of gas in oil zones. Gas saturation of the early production period (Figure 7a) shows the saturation was zero everywhere that reflects no free gas was present initially on the oil zone. A few months later (Figure 7b.), on July 1988 it shows that some gas saturated areas appeared having gas saturation about 0.8 as indicated by yellow color.



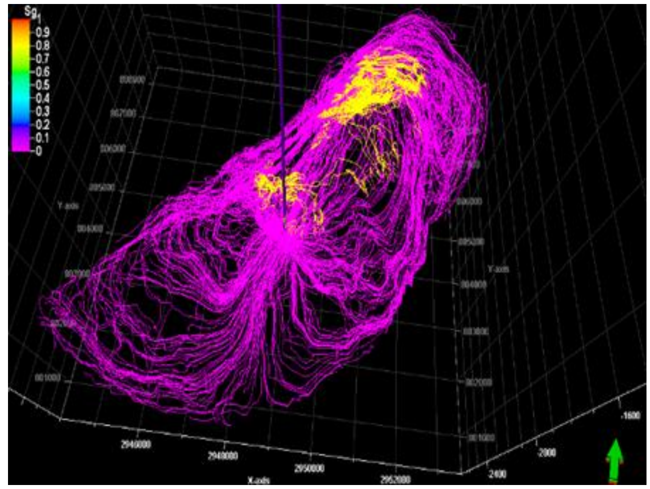
(a)



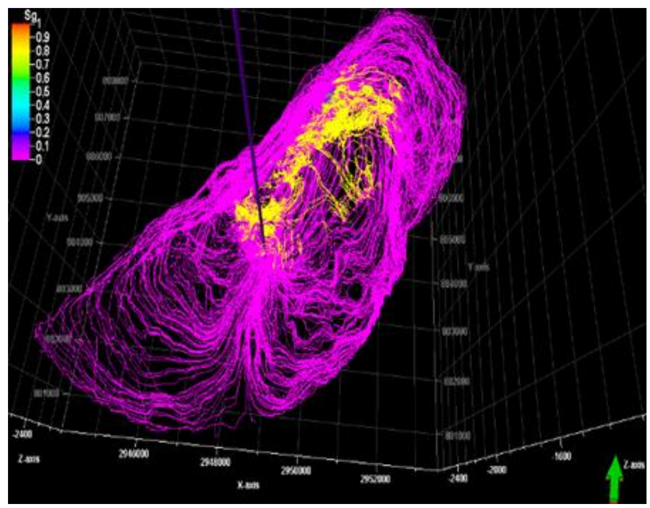
(b)

Figure 7: Gas saturation in streamlines; (a) on January 1988; (b) on July 1988

It implies that initially gas was dissolved in oil. As production goes on, the pressure was decreasing. When the pressure falls below the bubble point pressure, gas started to come out from solution and accumulated on the areas. In general, reservoir oil includes some natural gas in solution. When the pressure decreases with production, the pressure at which the first gas begins to evolve from the oil is defined as the bubble point pressure.



(a)



(b)

Figure 8: Gas saturation in streamlines; (a) on July 1989; (b) on July 1990

As the pressure was decreasing continuously with production, more and more gas was liberated from the oil and accumulated in the oil zone. Figure 8 shows this increasing trend. Gradually the oil zones around the well SY-7 were becoming saturated with gas. The gas was flowing with the oil resulting sharp increase in gas production that we observed in production data (Figure 6). Due this continuous pressure drop as a result of production, more and more gas came out of solution from oil. Gas saturated areas (Figure 9) increases with time till the end of the production period.

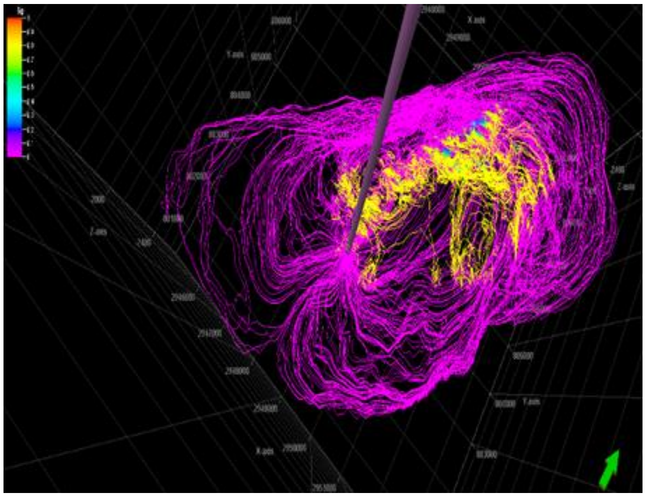


Figure 9: Gas saturation in streamlines on July 1994

As a consequence, the viscosity of oil was increasing continuously due to the liberation of solution gas. Oil was becoming more and more viscous gradually. Viscosity and flow rate are inversely related, viscous oil has higher resistance to flow. Therefore, oil in the reservoir did not flow easily as in earlier condition.

Furthermore, after going out form solution, gas was segregated and accumulated in oil zones that made reservoir a three phase fluid system. When multiple phases are present in a porous media, we need to consider the relative permeability of individual phases. Relative permeability of individual phases changes with changing saturation. Figure 10 shows gas-oil relative permeability curve for Haripur oil field where K_{ro} (sand) and K_{rg} (sand) represents the relative permeability of oil and gas respectively. It has been created using PVT data. It shows clearly when the gas saturation is more than 0.6 relative permeability of gas is 0.8 to 1. Therefore, in oil zones where gas saturation is 0.8, no oil can flow.

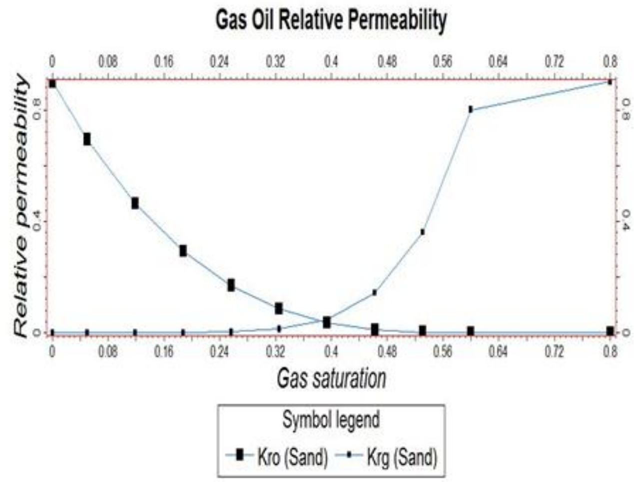


Figure 10: Gas Oil relative permeability

Furthermore, gas saturated areas also acted as oil flow barrier within which no oil could flow through. This flow barrier was increasing with the increasing of gas saturated zones with time.

V. Conclusion

The alteration of the properties of reservoir fluid system during production was responsible for premature production halt. Precipitous pressure drop during production caused gas coming out from solution and created gas segregated areas in oil horizon. Gradually oil was becoming more viscous and more resistance to flow. Also, gas segregated areas created oil flow barrier. As a consequence, oil flow rate decreased sharply and the production was abandoned prematurely. The production should have carried out with adequate pressure maintenance program to avoid this adverse consequence and sustain production for longer period.

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