The Impact of Sealing Fault on Enhanced Oil Recovery - A Case Study from Northern Part of Balol Field.

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Summary

The existence of fault has an important role in EOR activity. In northern part of Balol field which is a part of Cambay basin, EOR scheme had been implemented during the year 2002. Performance review showed that oil recovery from this heavy oil belt was not as per prediction. After the interpretation of 3D seismic data faults were identified and injectors-producers in the EOR scheme were repositioned. Considering the fault geometry analysis of GC data and production data verifies the presence of fault as a barrier to fluid flow, reducing oil production and limiting the effect of air injection and pressure support.

Introduction

Balol field of Cambay Basin is a part of heavy oil belt (Fig-1) with crude oil viscosity ranging from 50 to 200 cps at reservoir condition of 70 degree C temperature. Due to high mobility contrast between oil and water primary recovery was low. In-situ combustion technique has been adopted for enhanced oil recovery (EOR). In-situ combustion involves ignition of the well and injecting air to sustain the burning of some of the crude oil which has a combined effect in terms of efficient displacement and mobilization of crude oil (Fig-2).

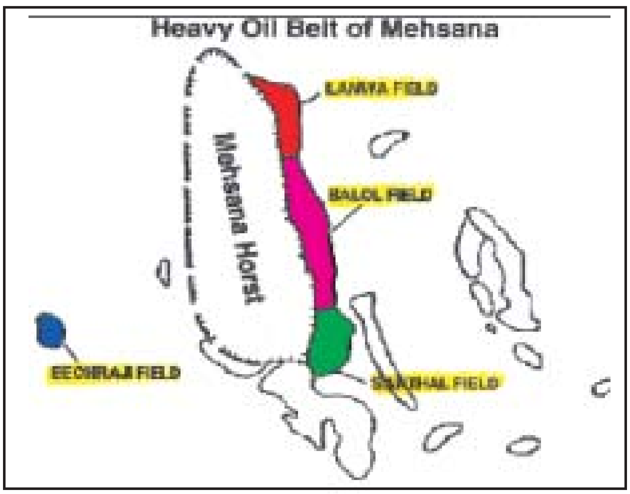


Fig. 1: Fields under In-situ Combustion process.

In March 1990 an In-situ combustion pilot was commissioned. The process was extended as Semi commercialization in January 1992 comprising one injector (BL#171) and four direct producers (BL# 32, 33, 34 and 38). On the basis of positive results two commercial schemes

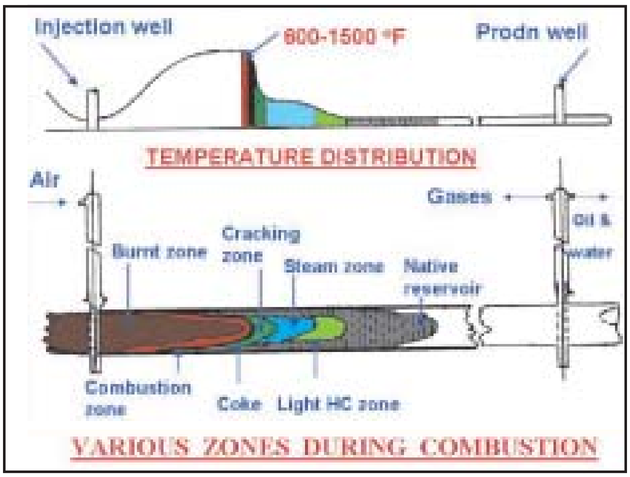


Fig.2: Schematic Diagram showing the principal of In-situ combustion.

were formulated and implemented in the southern part of Balol field in October 1997 and another in northern part of Balol field in May 2000. The study area is confined only to northern part of Balol field (Fig-3) and we will study the impact of fault on EOR scheme.

Geology of the area

Balol field is a narrow (approximately 1 km wide) and elongated (approximately 13 km length) in shape forming N-S trending homocline dipping 5-7 degree towards east.

The main oil bearing sands are Upper Suraj pay, KS-I, KS-II and lower pay of Kalol formation. These pay sands, deposited during the early and middle Eocene period represent the characteristic regressive cycle intervening between major transgressive shale deposits. The pay sands are underlain by Cambay shale and overlain by Tarapur Shale

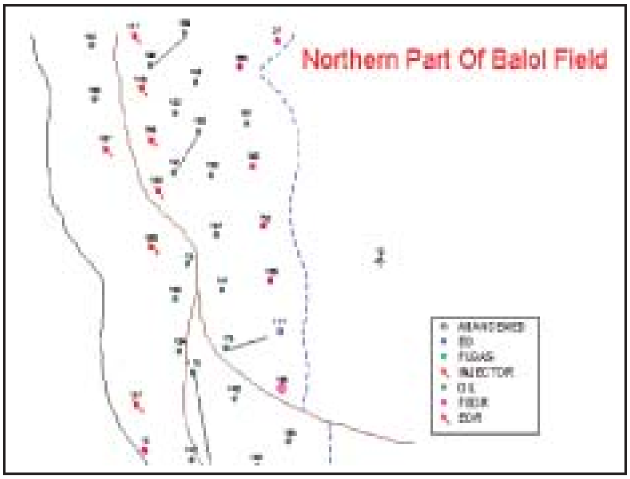
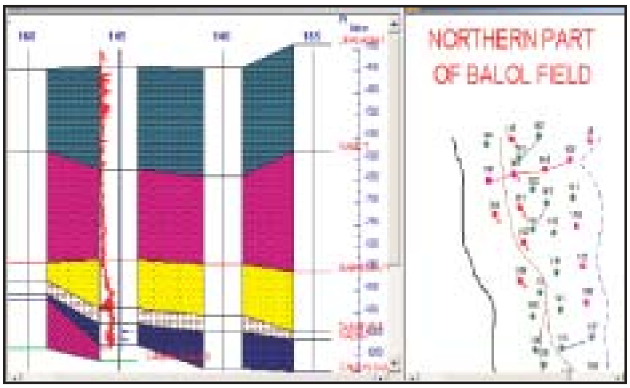


Fig.3 : Northern part of Balol field with injectors and faults

(Fig-4). The oil accumulation is limited to east by edge water aquifer. The oil water contact (OWC) varies from 995m to 1023m.



GC Data analysis

From Gas Chromatograph data (GC Data) analysis, the communication between injectors and producers with respect to air injection can be evaluated. Air injection was initiated in wells BL# 169, BL#157 and BL#167 in mid of 2000. Figure 5-A shows the trend of nitrogen movement (migration) towards north-south direction. Figure 5-B and Figure 5-C shows the same trend continued up to year 2003. This phenomenon indicates that there may be some barrier between the injectors and producers which resist the flow of fluid in west east direction. In view of the above facts, injection strategy in the northern part of Balol was reviewed and four existing producers BL#145,147,153 and 162 were converted as air injectors between the periods November 2003 to January 2004 and within few months' high Nitrogen concentration were recorded in the eastern part of study area (figure 5-D).

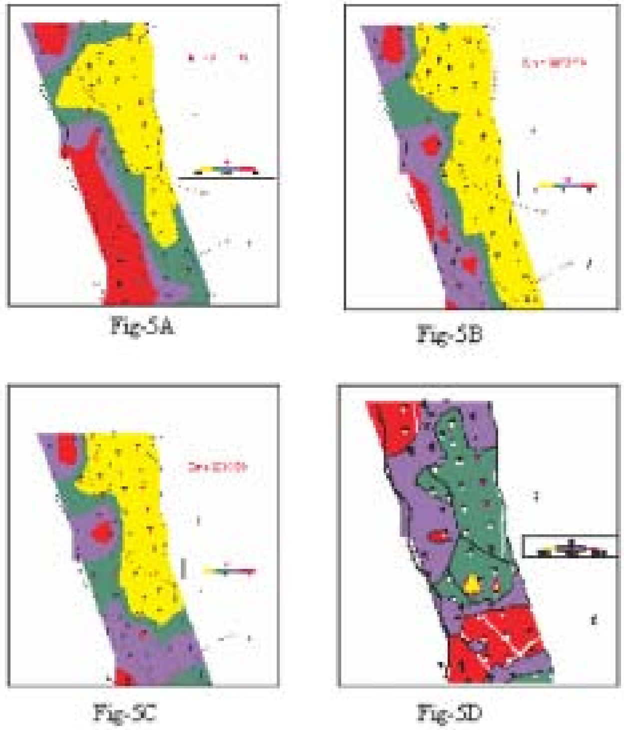


Fig. 5: Year wise Nitrogen movement

Oil production data analysis

With the initiation of the In-situ combustion process in the three injectors BL#157,167 and 169 no improvement in term of oil production could be achieved in producers wells BL#147, 145, 153 and 162 even after almost four years of air injection. The air from these injectors is preferentially moving towards up dip direction and has improved the oil production in some of the adjoining wells of Lanwa Field. This phenomenon indicates the existence of a sealing fault, which creates barrier to ISC process on western part of producer wells. After changing the injection strategy between November 2003 and January 2004 many wells improved their production performance. It is interesting to note that many wells, earlier on artificial lift (SRP), started self flowing after changing the position of injecting wells.

Seismic Data

The interpreted Seismic data shows that the field is dissected into various fault blocks with each fault block having its own hydrodynamic set-up and different OWCs. The most significant fault in the study area is FE-1, which is located at CDP no 100 of inline 170 (Fig-6) representing the eastern edge of the Mehsana uplift from upper Eocene

Fig. 6: Seismic section inline-170 with faults.

to recent. The Fault FE-2 is located at CDP no 180 of inline 170 about one to two kilometers east of FE-1 fault. The FE-2 fault is extending up to inline 90 at CDP 230, while fault FE-3 runs from CDP no 265 of inline 90 to CDP no 340 of inline10 (Fig-7). Time slice at two way time level 620 ms clearly validate the existence of faults that have been mapped in seismic lines. The general trend of the faults on inlines, exhibit NNW-SSE to NNE-SSW trend and fault adjoining the horst block coincides with the pinch out limit of Kalol sand. All the faults are normal in nature and run parallel with similar trend. Figure-8 shows the position of the FE-1 and FE-2 faults with injectors BL-169,157 and 167 and repositioned injector BL-147,162,145 and 153. The fault FE-2 is creating a barrier for the injectors BL-169,157 and 167 due to which ISC process towards western part of the field was affected.

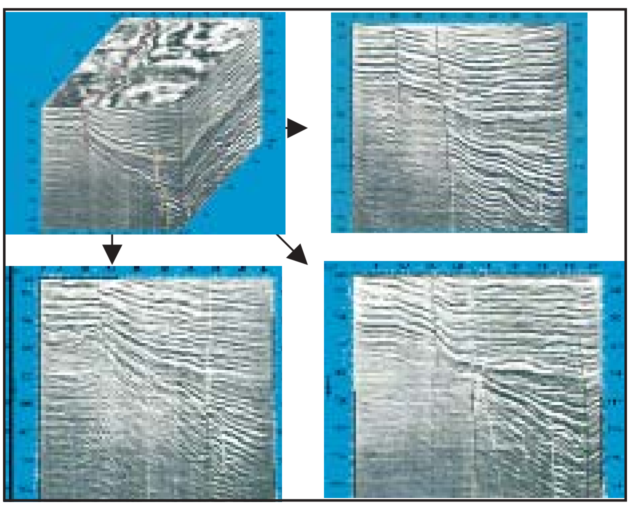


Fig. 7: 3D cube with seismic inlines 170, 10 & 150

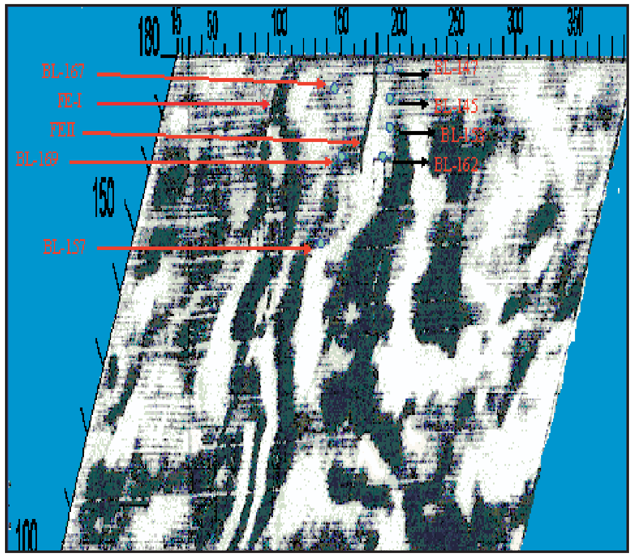


Fig. 8 : Time slice showing position of injectors and Fault

Conclusion

The use of 3D seismic data in development of an oil field is an integral part of reservoir management. This study has clearly demonstrated the impact of faults in movement of fluids in an oil field. Hitherto the reservoir management / simulation tools were not capable of handling complex fault patterns and the same were either simplified or ignored resulting in inconsistent forecasts / history matches. However, recent software / tools are able to handle complex fault pattern and incorporate faults in their workflows. It is imperative that fault geometries / properties are suitably represented / incorporated in such tools for obtaining optimum results, which will lead to efficient reservoir management.

Acknowledgements

The authors wish to thank Shri A.K.Gupta, ED–Asset Manager and Shri R.N.Bhattacherya, DGM (R) –SSM, Mehsana Asset for the encouragement and permission to publish this paper. The authors also thank Sri Vinod Kumar for rendering necessary suggestions. The cooperation from officers of Balol and Santhal Sub-surface group of Mehsana Asset is thankfully acknowledged

Views expressed in this paper are that of the author(s) only and may not necessarily be of ONGC.

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