

An Overview of Santhal Field, an EOR Implemented Field of Cambay Basin, Inferred from 3D Seismic

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Summary

In-situ combustion process has been implemented in Santhal field on commercial scale since 1997 for enhancing the recovery of heavy oil. During performance reviews of the wells involved in EOR process it was observed that behavior of some of the wells does not confirm to prediction/ anticipation based on the existing geological model. This paper deals with modification/up gradation of existing geological model incorporating faults interpreted from 3D seismic data. The revised/improved geological model explains the fluid movement behavior more satisfactorily and can be used for placement of future wells for further enhancement of production.

Introduction

The Santhal field is southern segment of the heavy oil belt comprising Lanwa, Balol and Santhal fields located in North Cambay Basin (Fig.1). The heavy oil belt is a narrow, NW-SE striking, elongated strip, 30 km long and 1-1.5 km wide. Crude oil viscosity ranges from 60-200 cps at 17 degree API gravity. The average reservoir pressure and temperature are 100kg/ cm² and 70 degree C respectively at a depth of 990 m below msl. The density of crude oil is 0.95 gm/cc. Primary recovery from this field under active edge water drive is estimated to be 18 %.

This necessitated implementation of an enhanced oil recovery technique to produce more oil from this field. Extensive laboratory studies were carried out at IRS for selecting most appropriate EOR technique. The In-situ Combustion (ISC) process was found to be the most suitable enhanced oil recovery method for heavy Oil belt of Cambay Basin.

The ISC process was executed in KS-1 reservoir sand in Santhal field, primarily involves conversion of an existing oil producer to air injector by re-completion with heat shield, burner assembly and thermocouple run over tubing for temperature monitoring at the surface. The ISC process is very much effective in terms of heavy displacement of crude oil, reservoir pressurization with the formation of secondary gas cap resulting in added advantage of gravity drainage. Moreover, only small amount of in-place oil is consumed while the rest is displaced, banked and finally produced. A schematic diagram of the process is shown in Fig.2.

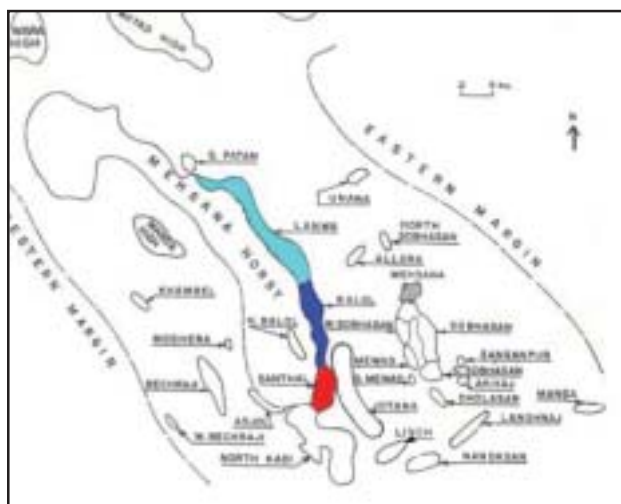


Fig.1 : Mehasana field of cambay basin.

In Santhal field around 15 MMT of ultimate recoverable oil was locked up that is being exploited under Insitu combustion process -an Enhanced Oil Recovery (EOR) method.

The ISC process has been indicating satisfactory results in Santhal field in terms of enhanced production. However, somewhere during implementation some anomalies have been observed which were prima-facie, inexplicable, hampering effective reservoir management of the field. The problem was analyzed taking into account all available data and a view emerged that there may be some subsurface faults/barriers (not mapped so far) playing significant role in the movement of EOR generated fluids. The recently acquired and processed 3D seismic data was interpreted with an objective to analyze the effect of

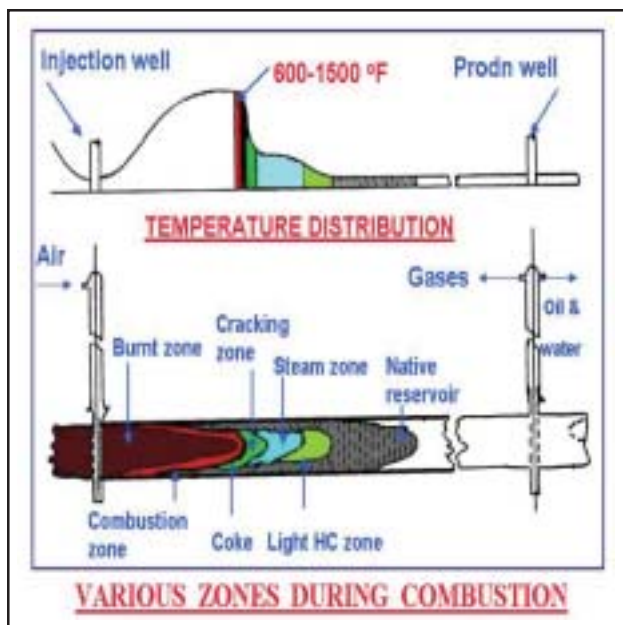


Fig-2 Schematic diagram of In-situ combustion

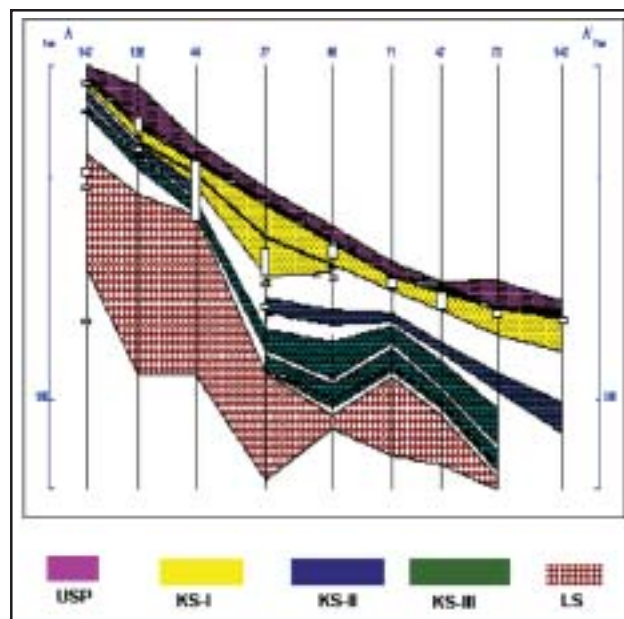


Fig-3 Cross section W-E (central part)

identified faults on the performance of ongoing ISC process and to take necessary corrective measures.

Geological setting

Santhal field is a North-South oriented monocline bounded towards west by Mehsana Horst and dipping towards east. The 150 m thick arenaceous section within Kalol formation of middle Eocene age, occurring at a depth of about 900m constitutes the reservoir. All the three reservoir units viz. KS-I, KS-II & KS-III of heavy oil field of Cambay basin are developed in this field (Fig 3). KS-I is further divided into four sub layers i.e. A, B, C & D. Similarly KS-II has been divided in five sub-layers A, B, C, D, E and KS-III is divided in three sub-layers A, B & C. These sub-layers are separated by Shale layers of varying thickness. The average porosity is 28% and permeability ranges from 8 to 15 Darcy.

Seismic interpretation

The existing geological model did not incorporate any faults. Interpretation of available 2D seismic data was not of much help as the seismic grid was discontinuous and had large data gaps.

The newly acquired 3D seismic data over Santhal field was interpreted for updating geological model. The VSP data of six wells was used to identify/calibrate the Kalol top

reflection event. GPS Location data of 202 wells were used to facilitate generation of a composite base map. Six longitudinal faults FE1, F1, FW1, FE2, and FE3 & FE4 (Fig4 & Fig5) running parallel or sub parallel to North-South have been identified over the area. (Fig 6) One of the faults FE1 is structure building fault close to Mehsana Horst The faults F1, FE2, FE3 run parallel to the structure building fault FE1 and are downthrown towards east with magnitude of throw varying between 5 to 10 ms. two way time. Fault FE1 is downthrown towards west by about 10 ms. The fault FW1 joins the fault F1 and together they demarcate a small high.

Time structure and Depth structure maps with faults (Fig7 & Fig8.) are prepared. Earlier structure map of the field is shown in Figure 9. Kalol sands of Santhal field are

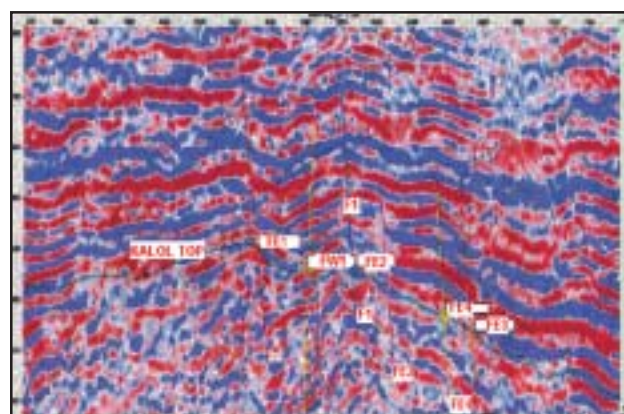


Fig-4: In-line- XX showing different faults and Kalol Top

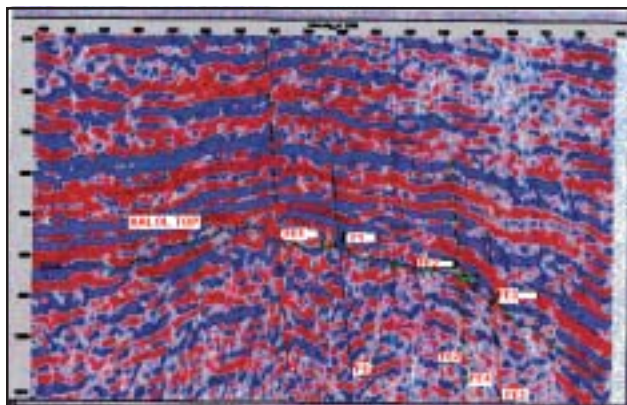


Fig-5: Inline-YY showing faults and Kalol top



Fig-7 Isochron map on top of KS-1

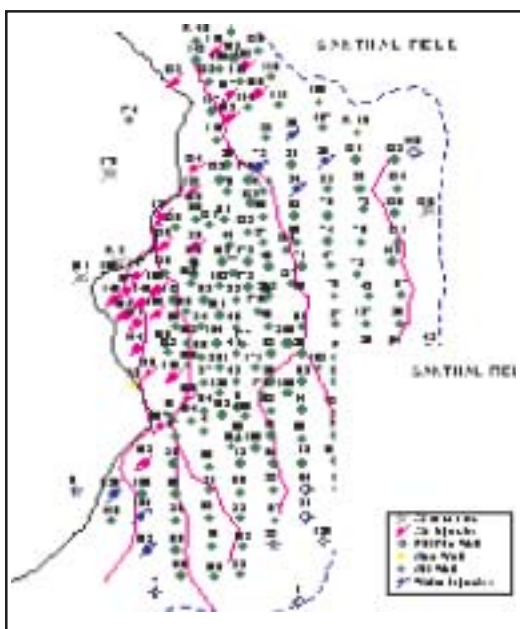


Fig-6 Santhal Field with well location

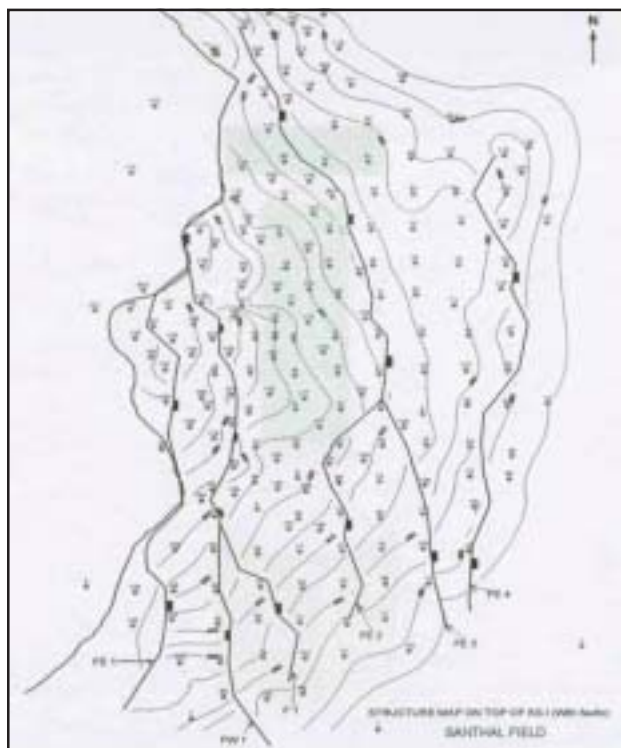


Fig-8 Structure map on top of KS-1 with fault

thinly laminated layers of sand and shale and one obvious implication of the mapped faults is possible juxtaposition of one layer with another across the faults.

Reservoir studies

The production data of Santhal field analyzed. Ascertaining the effect of the faults on the ISC process was found to be very difficult due to injection from updip and downdip of faults, reservoir heterogeneity and multilayered & commingled production. However the production performance indicates that most of the enhanced production comes from the wells falling in the direction of the flue gas

migration .It was observed that wells located in the vicinity of the faults FE1, FW1& F1 get early affect of the process. That means the faults acts mainly as preferential conduit for the gases.

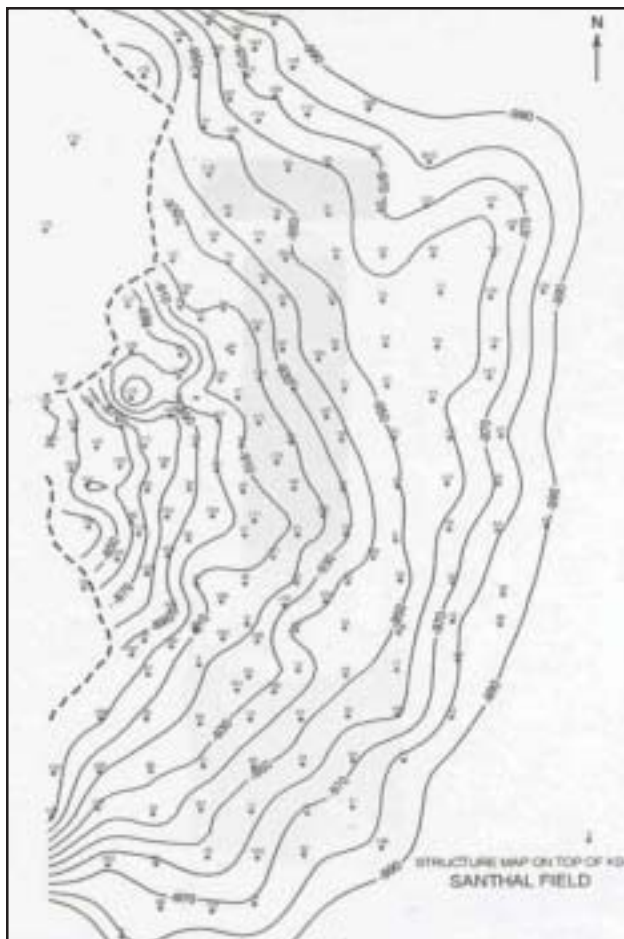


Fig-9 Structure map on top of KS-1(without fault)

Early effect in far-off wells

From Nitrogen (N₂) mapping (Fig 10) and study of chronology of invasion of the flue gas in the wells located near these faults, it was observed that SN#A,B were affected by flue gas in early 1999, SN#A indicates high N₂ composition (42%) whereas wells SN#C,D,E located near injector SN#G , indicate below 10% during 1999. Further south SN#F and B#H indicated high N₂ percentage (around 55%) before middle of the year 2000. SN#C,D, E did not indicate presence of N₂ during this period.

Analysis of water cut behavior of the wells adjacent to faults FE1, FW1 & F1, indicate decline water cut in all the wells from 1999, even before occurrence of the flue gas in most of the producers. This may be attributed to (a) flue gas movement towards east of these wells retarding the fingered water encroachment from aquifer (b) positive pressure from top due to flue gas migration along faults FE1, FW1& F1.

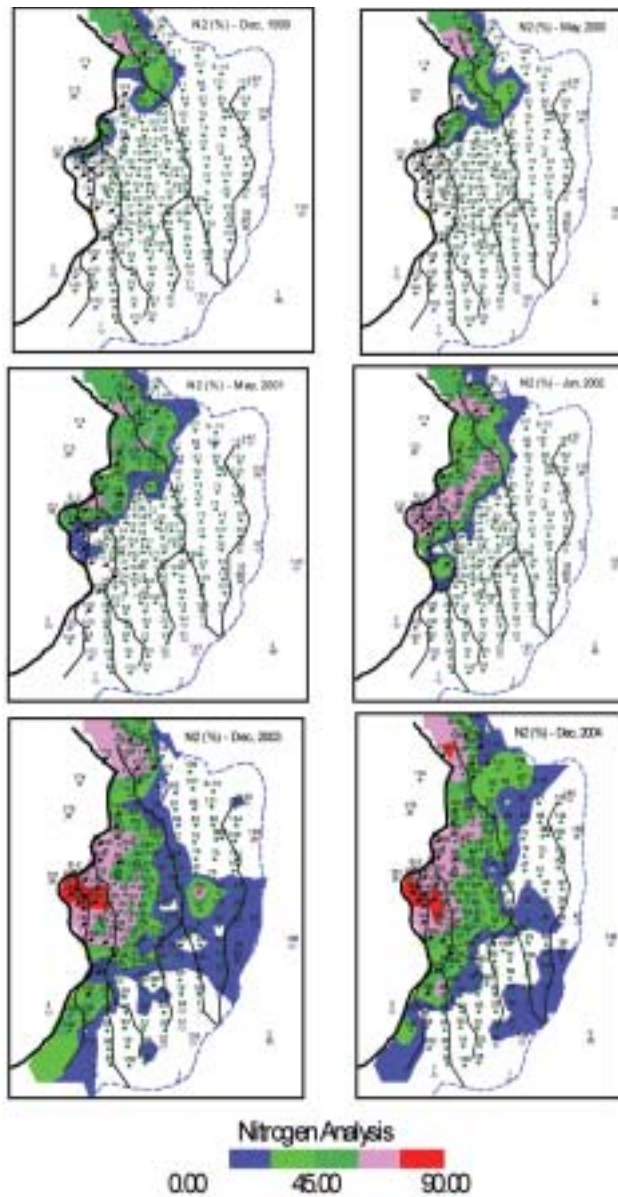


Fig. 10

Pre Mature Gas Out Of SN# A-

SN# A is located very near to fault F1 in an area of very poor development of KS-1 sand. It was producing @ 5 m³/d of liquid with 5% water cut. The well gassed-out prematurely without any EOR production. The sands in SN#E are better than SN#B and the well is slightly away from the fault. This well has produced a little EOR oil with declined water cut for less than six months in the year 2000 before gassing out.

Occurrence of flue gases in un-targeted sands

Most of the producers are completed in multi layered along with targeted sands (KS-1&KS-11). It is difficult to study the behavior of sands in isolation, but few producers viz. SN#F (KS-111+ LS), SN#G (KS-11) and B#H were not completed in the targeted sand at that time. Occurrence of flue gases in the above wells may be due to communication between different sands and juxtaposition of sands across the faults or vertical movement of the fluid along the faults.

Fault F2 (F2&F3)

Preferential movement towards SN#J at the early stage of process leaving up dip wells SN#K and SN# D,C from injector SN#L indicate effect of fault F2 either in terms of partial resistance of fluid migration in dip direction and in terms of conduit like behavior of the fault F2 for flue gas. However at later stage flue gas migration is dominated by gravity segregation. The similar phenomenon is observed towards SN#M also.

Recommendation

As EOR scheme is being recast for dedicated injector/producer, the geological model need to be reviewed with consideration of faults. The envisaged data need to be generated throughout the field without considering vicinity of injection points and future wells should be drilled away from the faults. Recently 11 high-tech horizontal wells and one high angled well planned to drill taking into account of the faults.

Conclusion

1. Identified faults are non sealing in nature. Moreover, they appear to have a role in terms of preferential migration of EOR generated fluids.
2. Faults FE1, FW1&F1 seems to provide conduit for movement of gases.
3. Fault F2 acts as conduit with temporary obstruction in flue gas migration from the injector SN # L.

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

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