

Reservoir Monitoring Through Cased Hole Formation Resistivity Tool- A Case Study from Sobhasan Complex Mehsana Asset, Gujarat India

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Abstract

Enhancement of oil recovery in mature field like Sobhasan complex requires a close reservoir monitoring of pressure as well as hydrocarbon saturation with time. In comparison to the pressure, saturation in reservoir is always been ignored. Knowledge of variation of saturation with time helps for better understanding depletion of reservoir and thus helps to decide better completion and perforation policies.

Sobhasan Field located in the Ahmedabad - Mehsana Tectonic block of Cambay basin spread over 40 Km², extends 25 km to the north of Mehsana city and upto Dholasan Village in the south. It is the 2nd largest producing field of Mehsana Asset. Sobhasan Field was discovered in 1968, since then hydrocarbon is being exploited from multilayered reservoir of Kalol, Sobhasan, BCS and Mandhali Pay Sands. Production from the field was started in 1969 @ 25 tpd, with continuous development of various oil pools/ reservoirs production from the field has touched to a peak of 1767 tpd during 1991, but in the subsequent year field experiences a continuous decline in oil production, as on date the field is producing @ 1102 tpd. Increasing water cut in peripheral wells of Kalol and Sobhasan Sand are the major reason for decline in oil production. This needs reservoir monitoring through a better and improved technology. In this regard Cased hole formation resistivity tool have been used to know the movement of OWC, identification of bypassed oil and thereby extent of depletion of reservoir. Study reveals the movement of OWC, which helps to carry out Water shutoff jobs and relook into the perforation policy adopted earlier.

The case study presented in the paper describes a successful water shutoff operations in two wells of Sobhasan field from the kalol and Sobhasan Pays and the encouraging results were achieved with substantially decrease in Watercut and increase in oil gain. Studying these wells not only resulted in net oil gain realized but also helps to decide better perforation and completion policies for the other wells completed in these sands.

In this paper, the reason in choosing resistivity behind casing, acquisition and time lapse formation evaluation to monitor present saturation profile have been discussed in details. Comparison between original and present water saturation level immediately detects the depletion zones and the degree of depletion across perforated intervals. This is considered as an indication of rise in oil-water-contact or lengthening of transition zone.

Introduction:

Hydrocarbon Saturation is always vital to understand the dynamic condition of reservoir especially in matured and depleting reservoir. Time lapse saturation contrast, help to assess the movement of OWC, extent of depletion of reservoir and identification of bypassed oil with in oil wells. But cause behind change in saturation need to be confirmed before deciding the strategy for further exploitation. To confirm the cause, WOR and WOR' diagnostic plots were used. Analysis of these curves ascertain the need to acquire CHFR log. Study reveals the movement of OWC by comparing CHFR with open hole logging and thereby calculating the extent of depletion. Subsequently, it helps to carry out Water shutoff jobs and relook into the perforation policy adopted earlier. Besides, study also suggested its implementation in long run and over a field, considering its oil gain realized and improvement in recovery. This paper presents the case study of wells of Kalol and Sobhasan Sand of Sobhasan Complex Field.

Sobhasan Complex comprises of Sobhasan, South Sobhasan, Mewad, South Mewad, West Sobhasan and Kherwa Fields. It is located in the Ahmedabad-Mehsana tectonic block of Cambay basin spread over 40 Km², extends 25 Km² to the north of Mehana city and upto Dholasan Village in the South. Sobhasan Field was discovered in 1968 and put on production in May'1969 since then hydrocarbon is being exploited from multilayered reservoir of Kalol, Sobhasan, BCS and Mandhali Pay Sands. Production from the field was started in 1969 @ 25 tpd, with continuous development of various oil pools/ reservoirs production from the field has touched to a peak of 1767 tpd during 1991, but in the subsequent year field experiences a continuous decline in oil production, as on date the field is producing @ 1078 tpd. Increasing water cut in peripheral wells of Kalol and Sobhasan Sand are the major reason for decline in oil production. This needs proper reservoir monitoring through a better and improved technology.

Regional Geological Setup:

Sobhasan Complex, lies in the Mehsana – Ahmedabad tectonic block of Cambay Basin is one of the most prolific oil producing onshore fields in India and occurs in narrow elongated rift graben(Fig-1). Mehsana horst is a prominent feature in northern part of the block and it divides the block into eastern and western depressions. The Mehsana block, the northern block of Cambay basin is bounded by Kutch upliftment in the West and Aravali Hills in the East. The Cambay basin is an N-S trending rift bounded to east by eastern and western margins with N-S trending faults. Northern part of Cambay basin is mainly affected by extensional tectonics, the major structural element, which divides the main block into two distinct regimes with series of parallel horst and graben in eastern part and while major depression in the center with prominent eastern and western rising flanks. Two major NE-SW trending transfer faults form the Northern and Southern boundary of the Mehsana Block. Sobhasan structure is a doubly plunging anticline with numerous local lows and highs of varying trends from NW-SE to NE-SW with structure building faults trending N-S. Sobhasan structure is mainly producing from Kalol, Sobhasan, BCS and Mandhali sands. Here case study of wells completed in Kalol and Sobhasan Sands are discussed in detail so more emphasis have been given to these sands.

Reservoir Performance Analysis :

Kalol sands are developed between two prominent shale layers called Tarapur Shale and upper tongue of cambay shale characteristically developed in South Sobhasan and Mewad area mainly deposited in fluvial environment. Six oil bearing sands have been identified viz. KS-I to KS-VI from top to bottom, where KS-V &KS-VI are the main producers. Cumulative production from this pay sands constitute 24 % of OIIP. In spite of higher cumulative production, the average reservoir pressure remain stabilized at around 120 Ksc from an initial pressure of 128 Ksc due to very strong aquifer support(Fig -2).

Field Block of KS-VI Sand contributed the major oil production of Sobhasan Complex in the past. This block is known for its permeability of the order of 800 to 1200 md and viscosity less than 4 cp. The pressure of this block is stabilized at 120 ksc due to large aquifer support. The peak production from this block was 540tpd in 1991 with 5 wells. At present block is producing

oil at an average rate of 62 tpd with 60 % water cut through 9 producers. The recovery worked out to be around 21% out of total OIIP of 7.04 MMt (Fig-3)

Sobhasan Main pay of Kadi formation is developed between upper and lower tongue of Cambay shale consists of sand, shale and coal layers. Two massive coal seams are present one at the top of lower tongue and another at the bottom of the upper tongue and are used as marker for correlation. Sobhasan pay sands are fluvial to marginal marine sediment deposited in lower deltaic regime with sediment input mainly from north. Sobhasan pay are divided into four pay units. viz. SS-I (SS-IA, SS-IB, SS-IC), SS-II (SS-IIA & IIB) and SS-III and BCS sands which are producing under mixed drive to depletion drive. For these pay sands initial reservoir pressure has declined from 143 Ksc to around 80-100 Ksc. The pressure scenario shows a partial aquifer support from the edge water drive. OWC is seen in some of the wells of the block at 1363.5 m. Till now 0.39 MMt of reserve has been exploited out of the total of 1.87 MMt of OIIP. The recovery worked out to be 21%.

Measurement Theory and Methodology:

Principle in an open hole log, CHFR tool is like a laterolog device where the resistivity is calculated by measuring voltage, that is generated by injecting some current in the formation and the resistivity could be computed, if the amount of the current and the voltage drop is measured. But, in the case of cased hole, conductive casing restricts the current to penetrate into the formation. Thus a low frequency current with high skin depth could leak into the formation and this leakage current measurement helps to find the resistivity of the formation.

Before calculating the saturation of depleted zone, CHFR log is compared with the open hole log of non depleting zones. After matching above two logs, general procedure is to find the lithology, porosity and saturations from open hole logs. Further saturations of the depleted zone is calculated by finding resistivity (R_t) from CHFR tool and keeping other parameters like volumetric information of matrix same as open hole log. The extent of the depletion can be determined by

$$\text{CHFR (Extent of Depletion)} = \sqrt{(R_t(\text{CHFR})/R_t(\text{Open Hole}))}$$

where $R_t(\text{CHFR})$ is the resistivity of the formation through CHFR and $R_t(\text{Open hole})$ is the resistivity of the formation through open hole logging. Thus for analyzing CHFR tool we make the assumption that the volumetric condition of the matrix does not change while the depletion of reservoir. Secondly substantial change in the salinity of reservoir makes the analysis of resistivity a bit complex. The extent of depletion of reservoir is calculated by taking the ratio of resistivity in open hole to cased hole.

Case Histories:

Case 1: Water shut off in kalol Sand Sobhasan Fields:

Well-X is located in South Sobhasan Field of Sobhasan Complex. The well was drilled in early Jan 1993 in crestal part of the KS-VI sand for the exploitation of undrained oil. Open hole Log indicated KS-VI developed in the interval 1269-83 m with OWC at 1279 m. Accordingly interval 1270-1274m was perforated, i.e. 5 m above the OWC. Subsequently, till Aug-10 well has produced 99,000 Mt of oil on self (Fig-4). Decline in oil rate along with high water cut was observed in Nov 2009, that prompts in an identification of the present oil level against perforated interval. To understand the cause of increase in watercut WOR and WOR' diagnostics curves (Fig-6) are plotted which shows the coning effect. For minimizing the effect X-linked polymer job followed by CSQ job was carried out in open interval 1270-1274m.

Subsequently, CHFR was acquired to know the current level of saturation against the perforation, movement of OWC and unswept oil if any. Log was analyzed and shows the good match in non reservoir zones. The depletion against top perforated interval is comparatively less than the lower perforated section and the present day oil saturation is lesser in the lower zone. It could be readily identified that the lower perforation is the main contributor of water. OWC was seen at 1276m which shows the rise of 3 m compared to open hole. Further the extent of depletion is determined and shown in Track. As depletion occurs, CHFR depletion indicator should be less than one as indicated. On the basis of analysis of log 1270-1272 (2m) is perforated. Results shows the increase in oil gain from 3 to 13 tpd and decrease in water cut from 80 % to 40 %. Till now around 2200 Mt of oil is realized. On the basis of this wells, current perforation policy is decided for the further exploitation of the KS-VI sands of this block.

Case 2: Water shut off in Sobhasan Sands of Sobhasan Fields:

Well Y lies in South Sobhasan Field was completed in Sobhasan-IA+IB Sands. The well was put on production in 1990 (Fig-5). Initially on the basis of open hole logging the sand thickness of Sobhasan-IA (5m) Sobhasan-IB (10 m) and Sobhasan-IC (6.5 m) was found. Interval 1425-1429m and 1436-1444m was perforated and shows the initial oil gain of 18 tpd with 40 % water cut. Since then it has cumulatively produced around 39400 Mt of oil. Before free water was reported in Apr -2008, this well was producing at 4 tpd with 85 % watercut. Again the analysis was performed using WOR and WOR' plots diagnostic plots (Fig-7) which shows coning effect with late channeling. Subsequently CSQ was carried out in interval 1425.0-1429.0 and 1436.0-1444.0 and USIT followed by CHFR was acquired. CHFR log shows a good match with open hole log in non depleting zones and shows saturation in 1424-1428m 1425-1437.5 and 1454-1458m. Thus these intervals were perforated resulted in revival from nil to 9 tpd presently. Till now around 2600 Mt of oil is realized in this well. By seeing the behavior the water shut off job was carried out in nearby wells in this block.

Conclusions:

Cased Hole formation resistivity measurement technique has been implemented successfully for reservoir management in Sobhasan Complex area. Evaluation helps to select completion zones in a better way thereby enhancing the recovery of reservoir. Monitoring through WOR and WOR' diagnostic plots provide greater understanding of the cause of depletion of reservoir. Technique in the future may be desirable to understand the dynamic condition of reservoir.

References:

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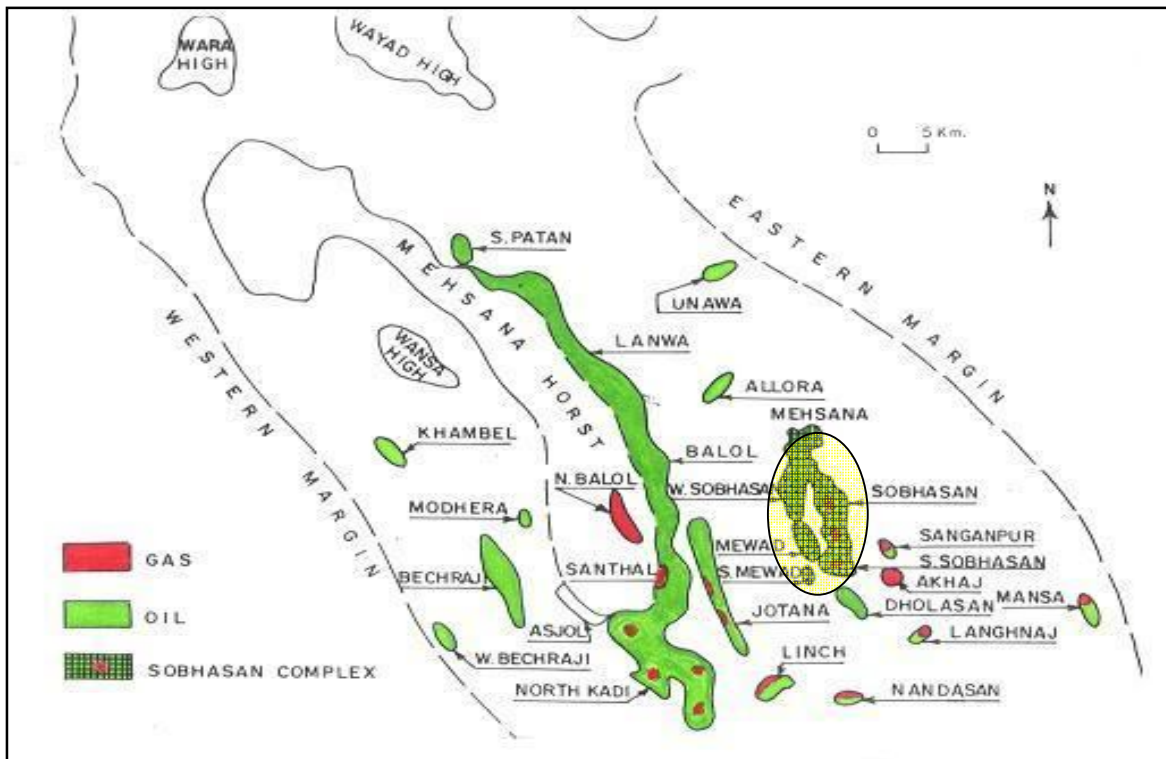


Figure 1: Tectonic Map of Sobhasan Complex and adjacent Fields of Mehsana Asset

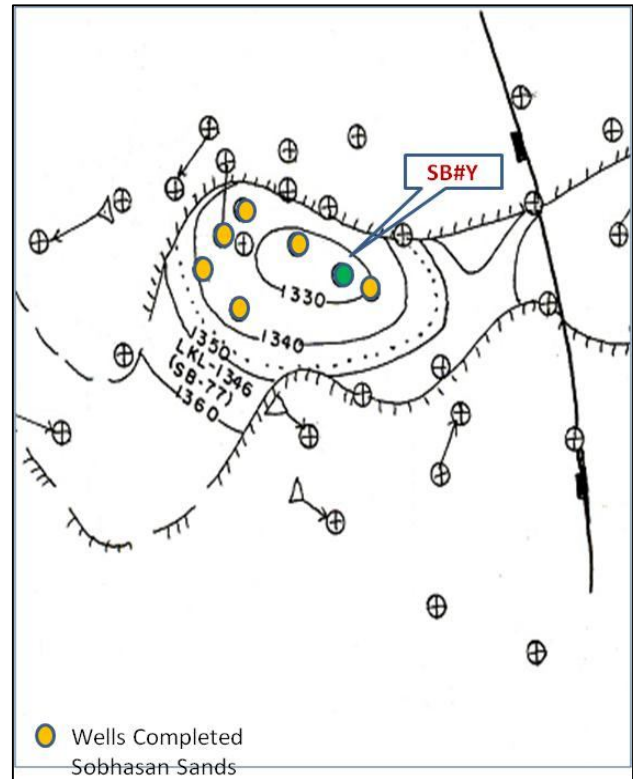
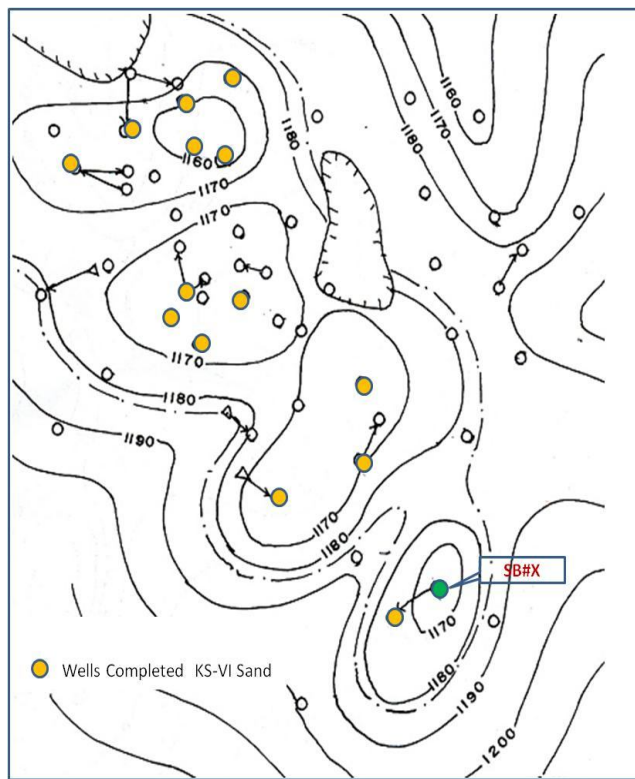


Fig 2: Structure Contour on top of KS-VI and Sobhasan Sands

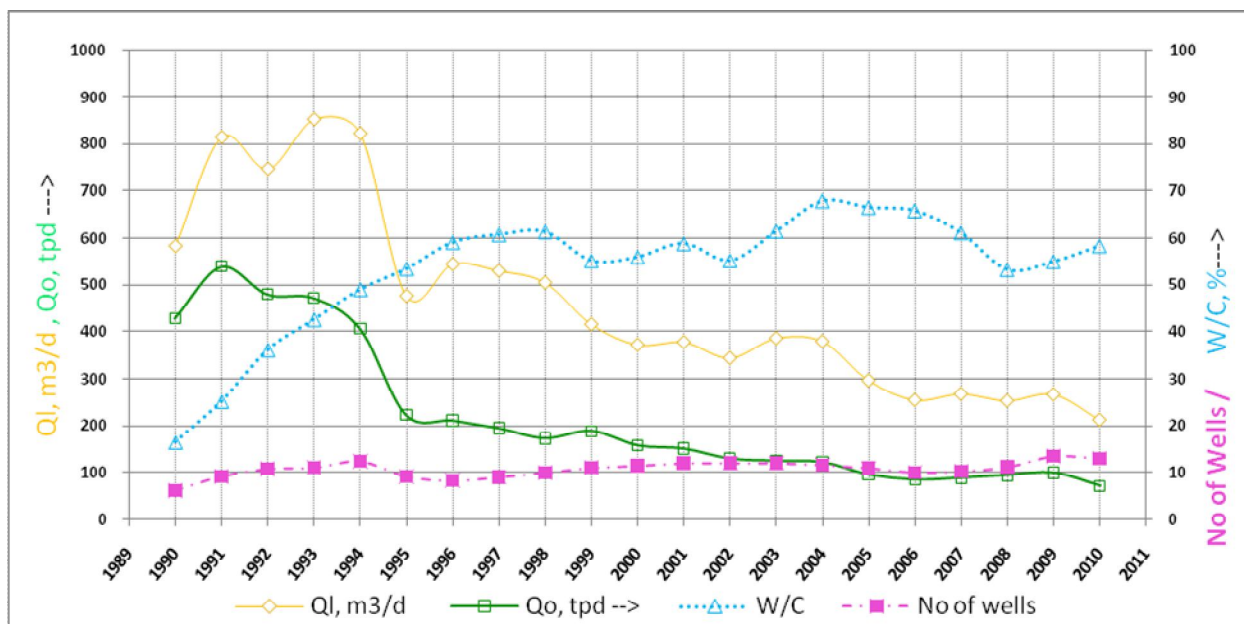


Figure 3: Production Performance of Field Block of Kalol-VI Sands of Sobhasan Complex

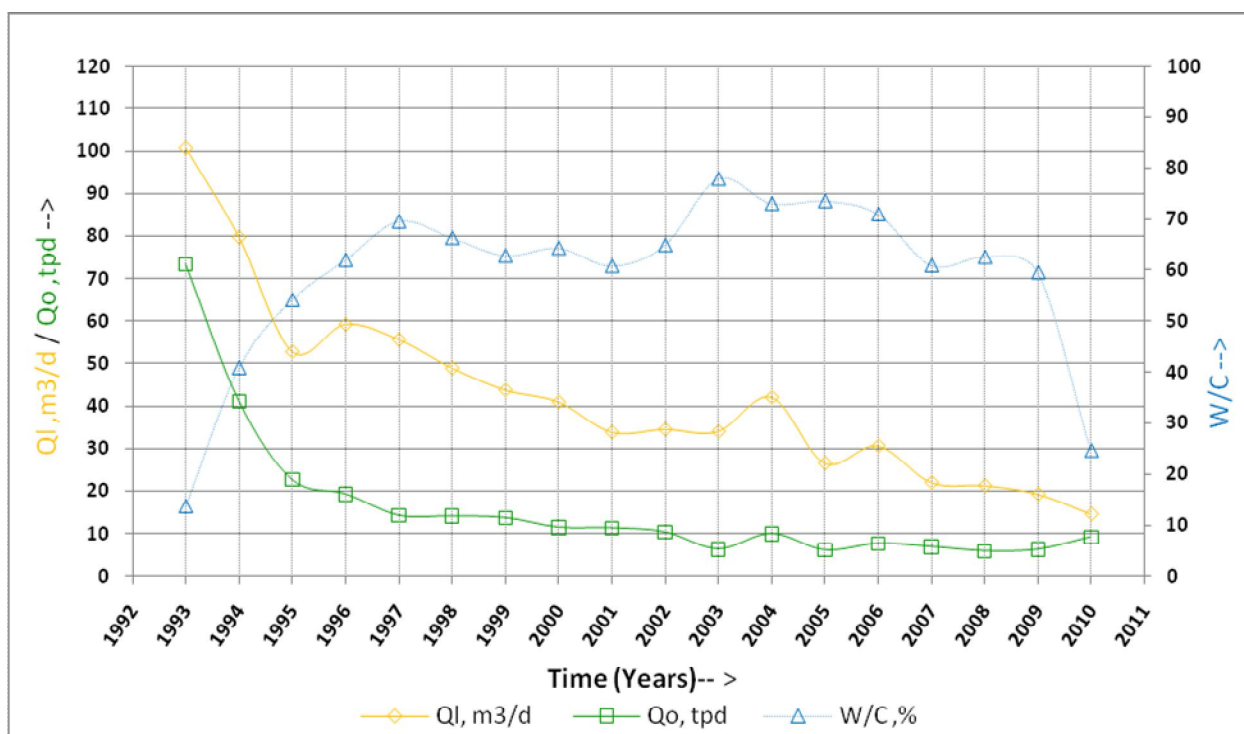


Figure 4: Production Performance of Well SB#X of Sobhasan Complex

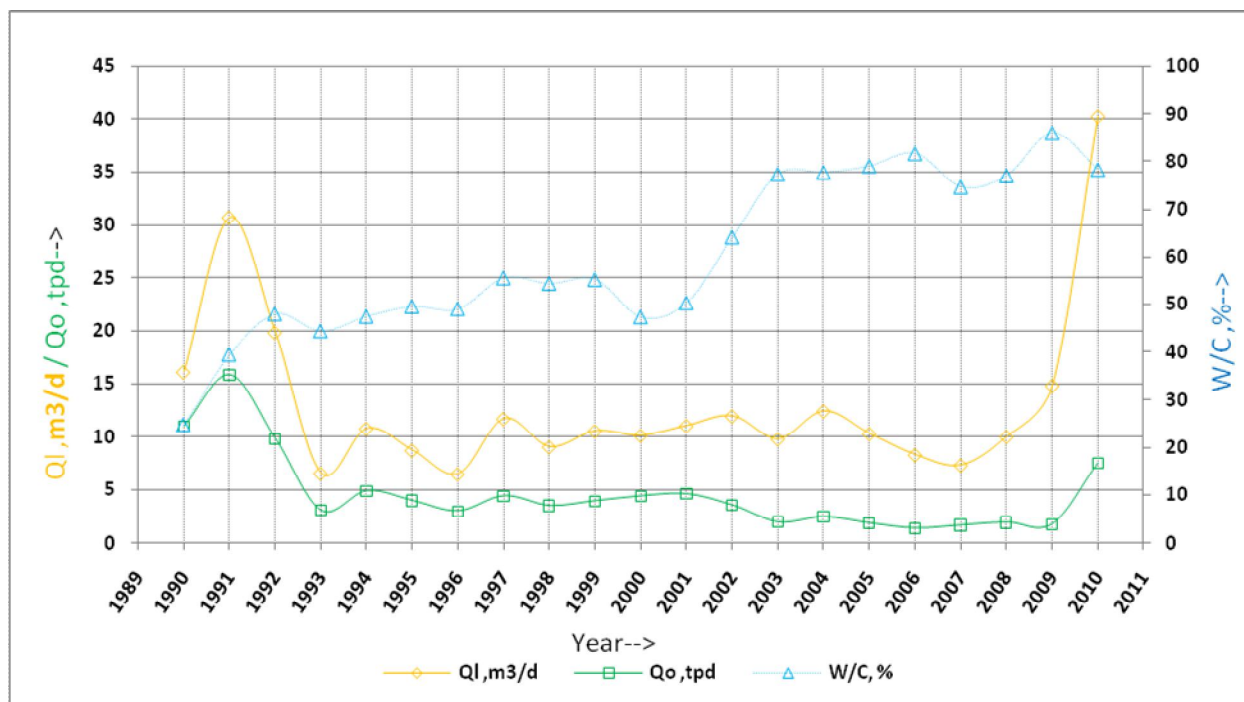


Figure 5: Production Performance of Well SB#Y of Sobhasan Complex

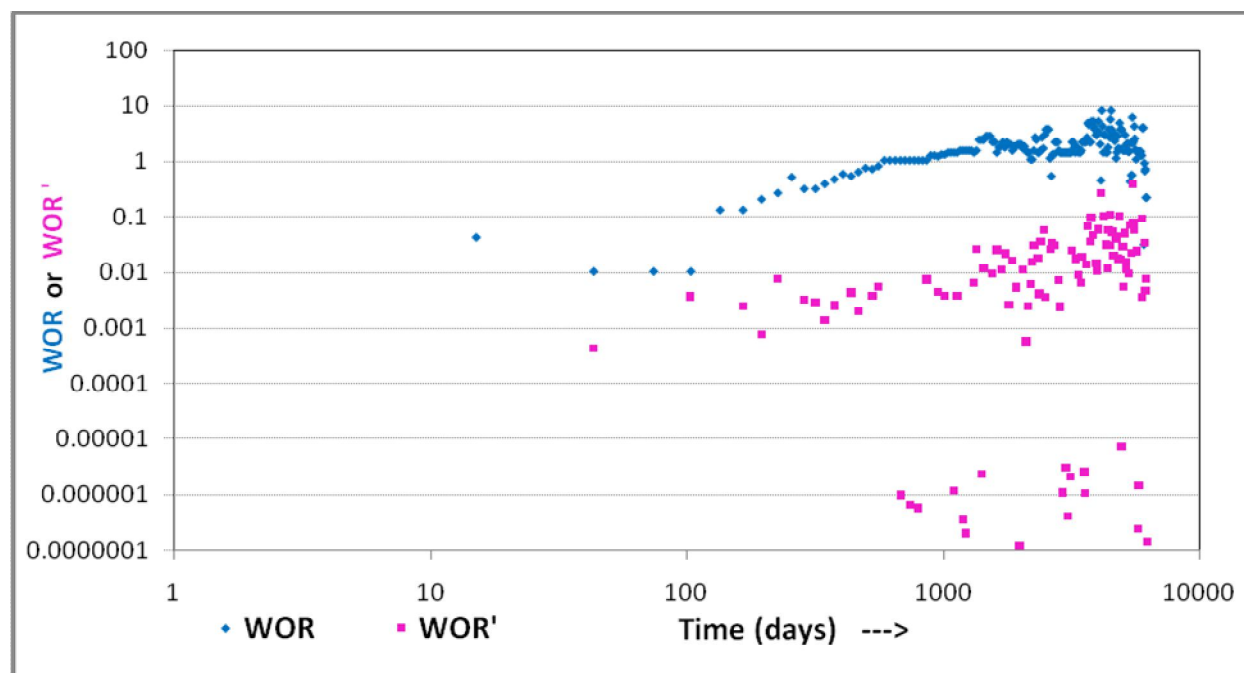


Figure 6: Diagnostic plot of Entire period of SB# X

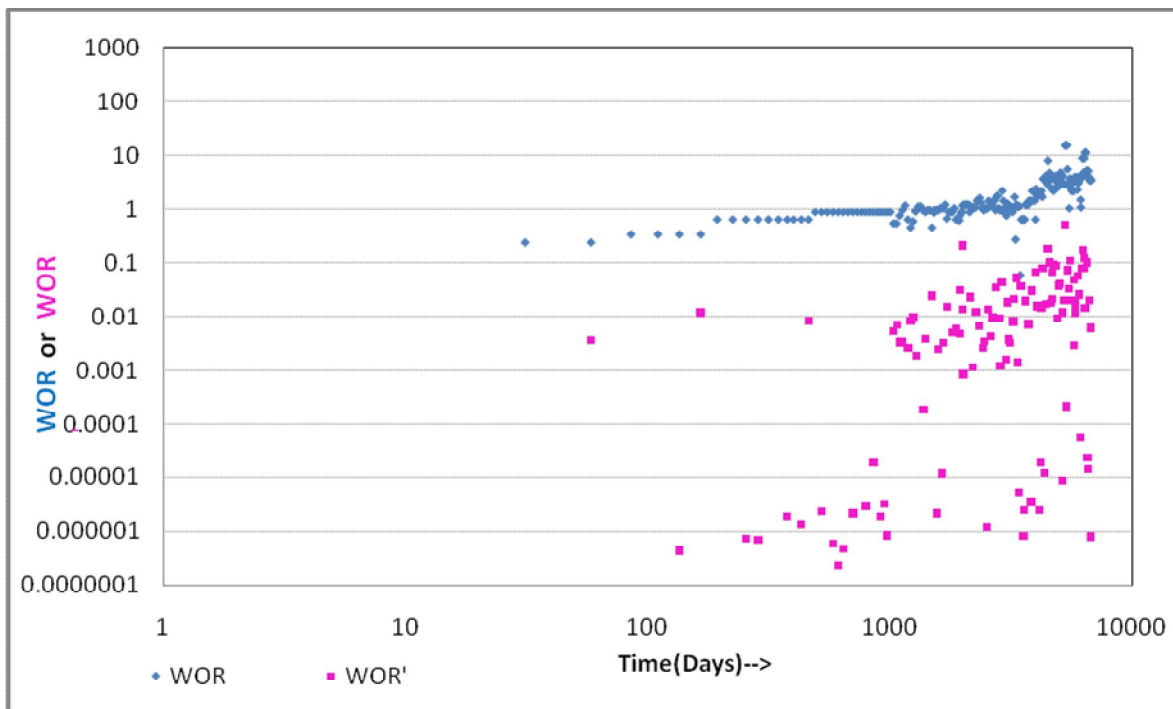


Figure 7: Diagnostic plot of Entire period of SB# Y

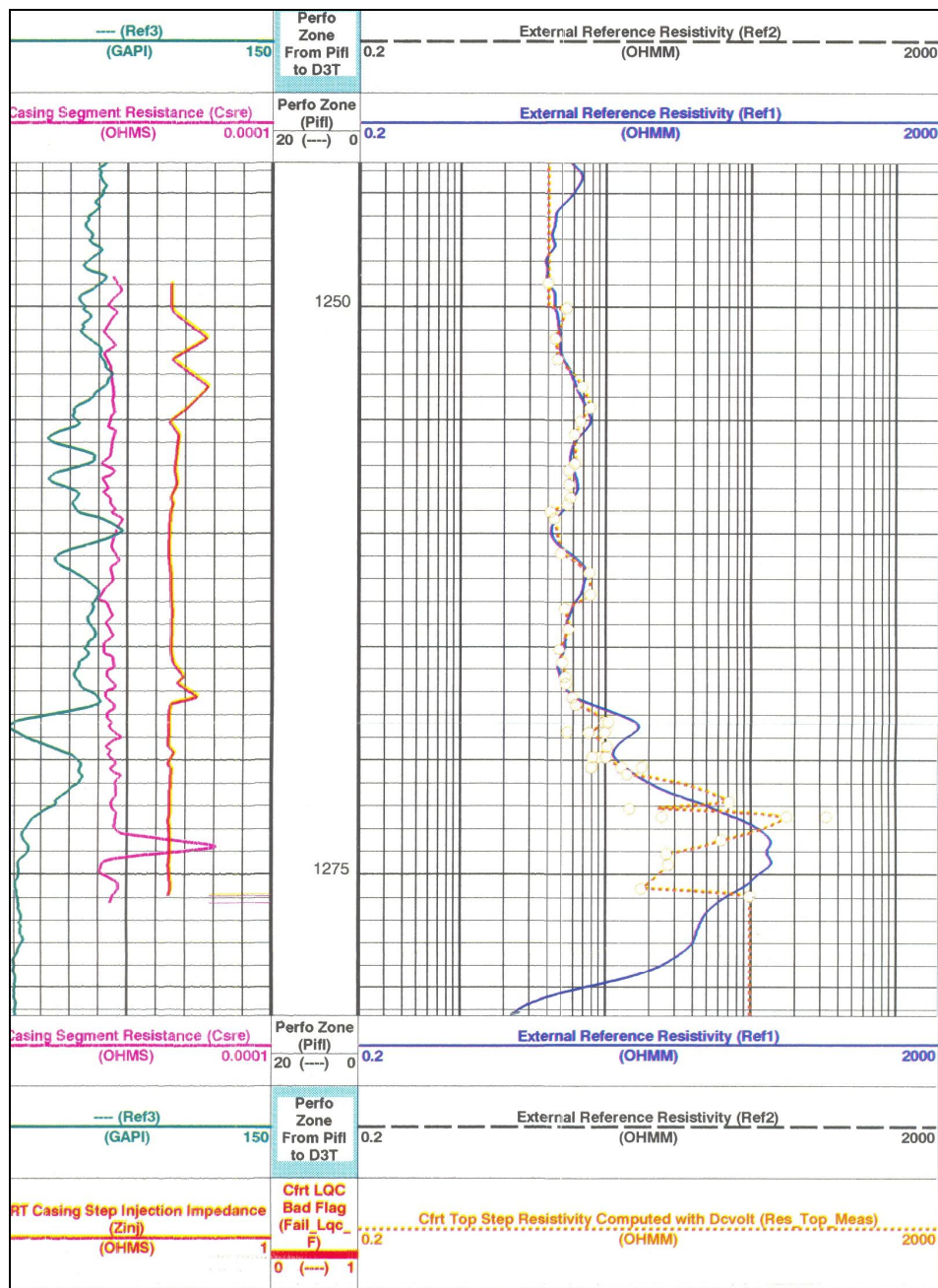


Fig 8 : Log motif of Well SB#X

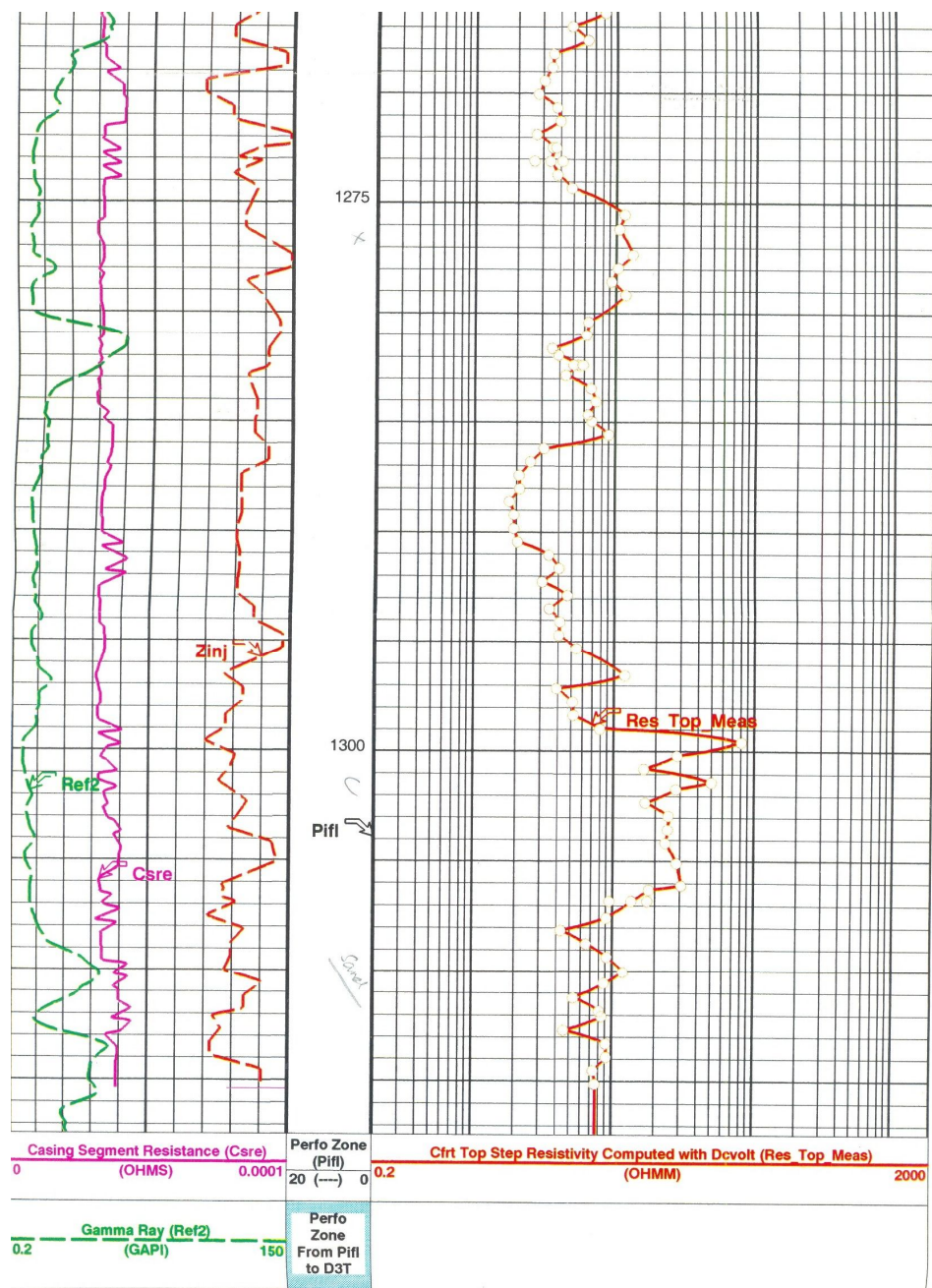


Fig 8 : Log motif of Well SB#Y