GEO India 2018

*PaperID* **AU455**

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# Pressure Maintenance a Dominant Factor in Well Productivity over Reservoir Heterogeneity: A Case Study from Cambay Basin, India

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**Key Words: Reservoir analysis, pressure maintenance, water injection, reservoir heterogeneity**

## Abstract

Cambay basin is one of the oldest producing basins in India. Multiple formations are under production in this basin with over 100 different reservoirs of varying sizes. Study area i.e. South Kadi field is situated in Ahmedabad-Mehsana tectonic block of this Basin and belongs to Paleocene to lower Eocene age. It was discovered in 1967 with reservoir units embedded within Older Cambay Shale. Main producing units of the field are lower Kadi pays which are discrete sand bodies having limited areal extent, occurring at depth from 1700m to 2200m. 12 different sands units have been identified in the area having varying productivity.

Present study deals with one of the reservoirs of the field viz. Sand-1 having 23 wells. Though there are multiple oil blocks in Sand-1, only two blocks i.e. Block-A & Block-B are considered in the present study. Block-A has 15 wells whereas block–B has 3 wells. Well performance of the block was analysed in context of log characteristics showing heterogeneous nature of reservoir. Four logs i.e. gamma ray, resistivity, bulk density and neutron porosity and sonic were used for the study. Values of these logs were extracted against perforations and cross plotted with gamma ray. Histogram analysis was also carried out for understanding the heterogeneity of the reservoir. Well performance was analysed in terms of reservoir pressure maintenance through water injection vis. a vis. reservoir heterogeneity. It was observed that pressure maintenance plays a dominant role in determining the cumulative oil produced from well over reservoir heterogeneity.

## Introduction

The study area is located about 50km (fig-1) from Ahmedabad city and falls in North Kadi-Sanand-Jhalora high trends of Cambay Basin. Cambay basin is mainly affected by extensional tectonics as indicated by the grabens, half grabens, synclines, synthetic fault blocks etc. The major lineaments trend is in NNW-SSE direction, i.e. Dharwarian trend. The other trend runs NE-SW (Aravalli trend), which divides the basin into number of blocks. Based on sequence stratigraphic correlation the hydrocarbon bearing layers of the field have been classified into Kalol, Mehsana, Mandhali & Kadi pays (fig-2). These have further been subdivided into several sub layers. Reservoirs of the field are divided into 12 separate sand bodies which are further subdivided into multiple independent HC pools. Sand-1 is one of the 12 sand bodies present in the area. There are many oil pool in sand-1 of which two have been in the present study i.e. Block-A & Block-B.

In block-A there are 15 well of which six wells are presently water injectors and nine wells are oil producers. In block-B there are three wells of which one is water injector and two are oil producers. Cumulative oil production from block-A is 1.32MMm$^3$ and from block-B is 0.11MMm$^3$. Pressures in the field are super hydrostatic but show a quick decline with production. In block-A the initial pressure was 229 kgf/cm$^2$ whereas in block-B pressure recorded in subsequent well was found to be 209 kgf/cm$^2$.

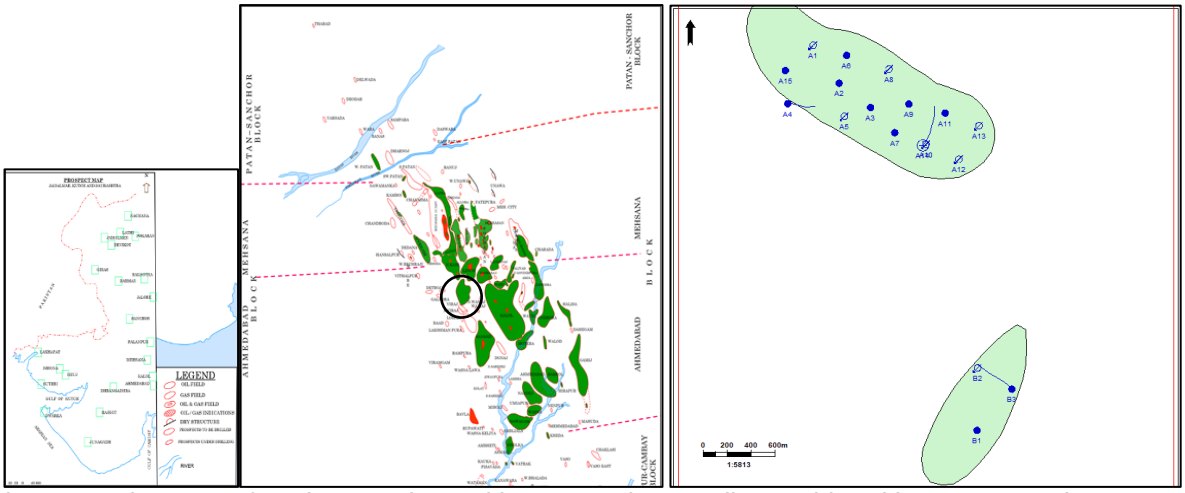


Fig-1: Location map of study area along with pay Sand-1 & wells considered in present study.

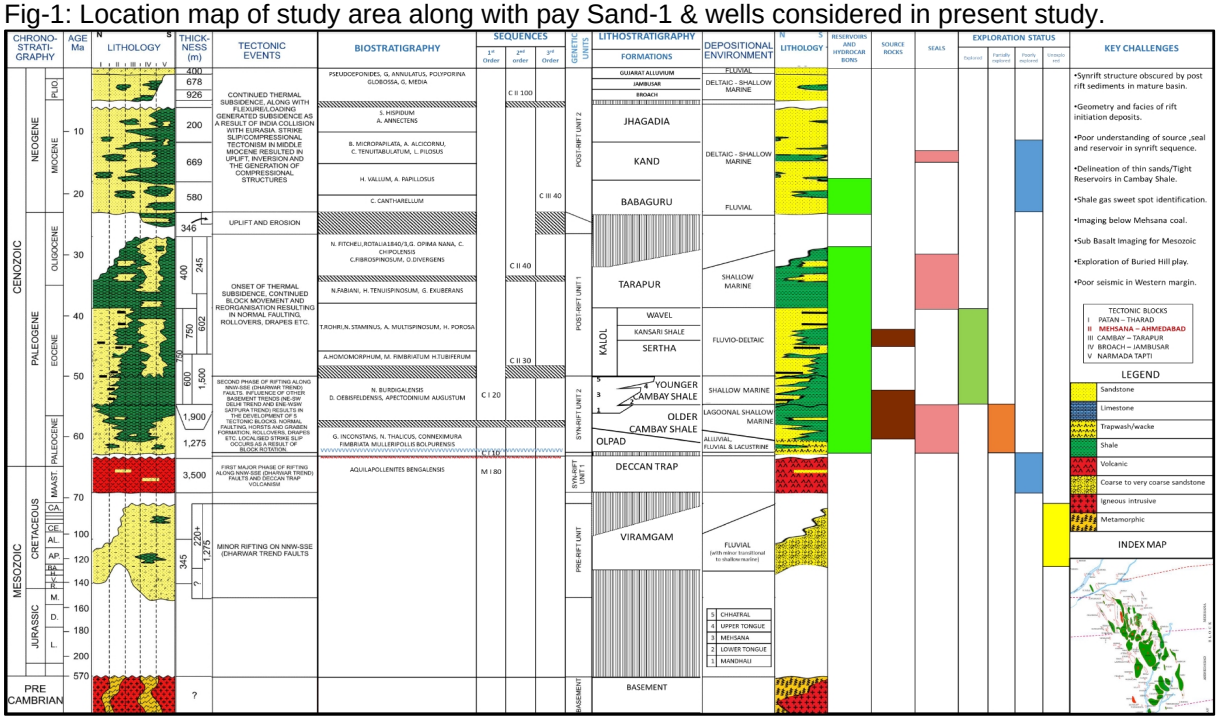


Fig-2: Generalized stratigraphy of Cambay Basin.

## Performance Analysis

## Block-A

Block-A contains 15 wells producing over different time ranges. Some well were converted to water injectors to maintain pressure in the block. The pool is well delineated by three more wells were drilled around the block which were tested dry. The first well in the pool was drilled in Mar-93 and has produced 0.117MMm$^3$ of oil. This well was later converted to water injector to support the declining pressure of the pool. The block in has cumulatively produced 0.85MMm$^3$ of oil through 15 wells which comes out to be about 0.057 MMm$^3$ per well of the pool. Since the reservoir is producing under depletion drive, pressure decline was observed. To arrest declining pressure of the block water injection was started in the block. Structurally the block is south east dipping reservoir and hence three water injectors were placed in the lower part of the block.

Pressure data of wells in this block is shown in figure-3. A1 is the first well in the block in which pressure declined from 209 kgf/cm$^2$ to 147 kgf/cm$^2$ in five years. The faster decline in the field was due to field producing under depletion drive. This pressure decline is mimicked by A5 where pressure dropped from 139 kgf/cm$^2$ to 135 kgf/cm$^2$ in 3 months with oil production of 1500m$^3$ only. The well was soon converted to water injector for pressure support of the area. Effect of water injection was visible as rise in water cut in wells A2 and A6 (fig-4 & 5). It is to be pointed out here that despite well A6 being closer to well A1 high water cut was first observed in well A2 indicating preferential movement of

water representing heterogeneity of the area. Two more wells A5 & A8 were later converted to water injector for pressure maintenance of the field. Three water injectors were place in structurally lower part of the field.

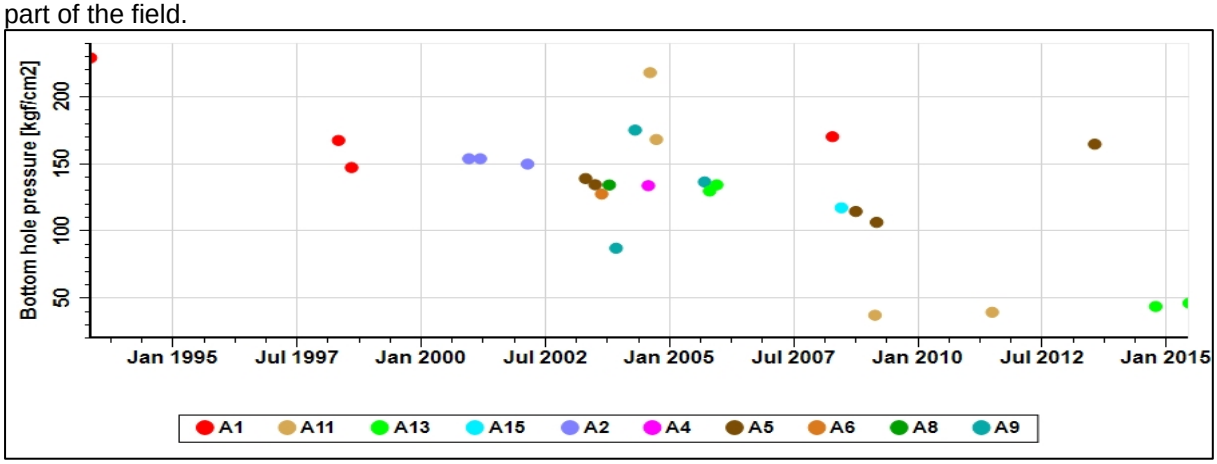


Fig-3: Pressure data of wells in block-A of Sand-1.

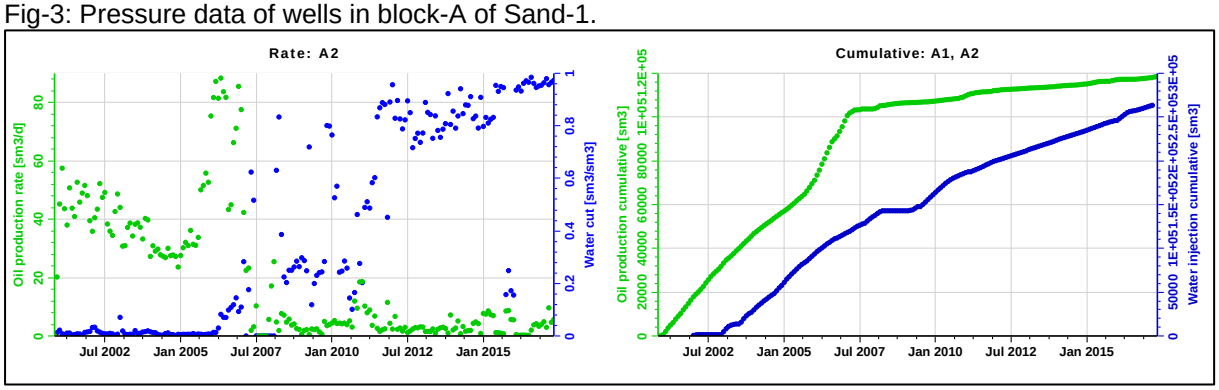


Fig-4: Production data of well A2 with water injection of well A1.

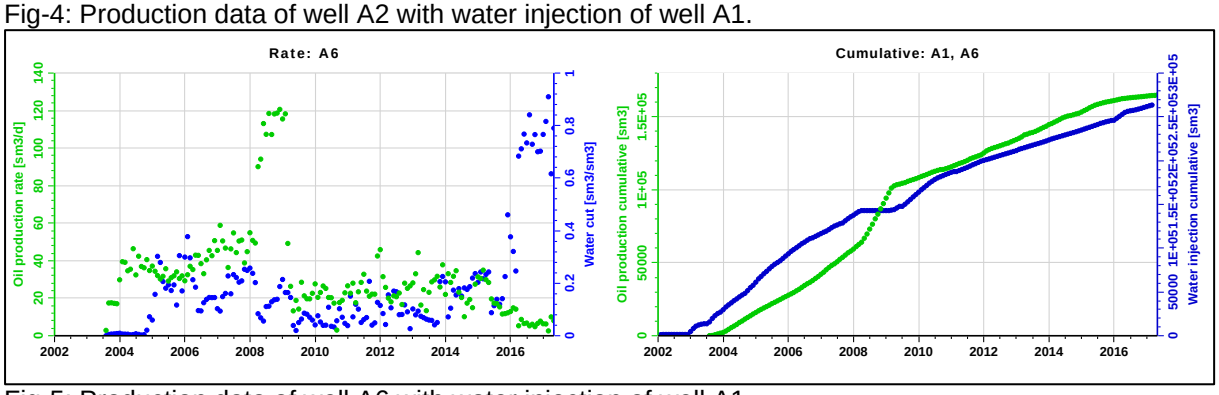


Fig-5: Production data of well A6 with water injection of well A1.

Well A11 situated in the deeper part of the area was opened with an initial pressure of 218 kgf/cm$^2$ which is very close to the initial pressure of the pool. But there was a sharp fall in the pressure of the well to 37 kgf/cm$^2$ in five years only. A nearby well A10 was converted to water injector in Oct-04. Effect of this water injection could be seen in farther well A13 very early compared to nearby wells A11 & A12 (fig-6 & 7). Pressure behaviour of well A11 also show sharp decline with production, whereas pressure in well A13 declines comparatively at slower rate indicating pressure support.

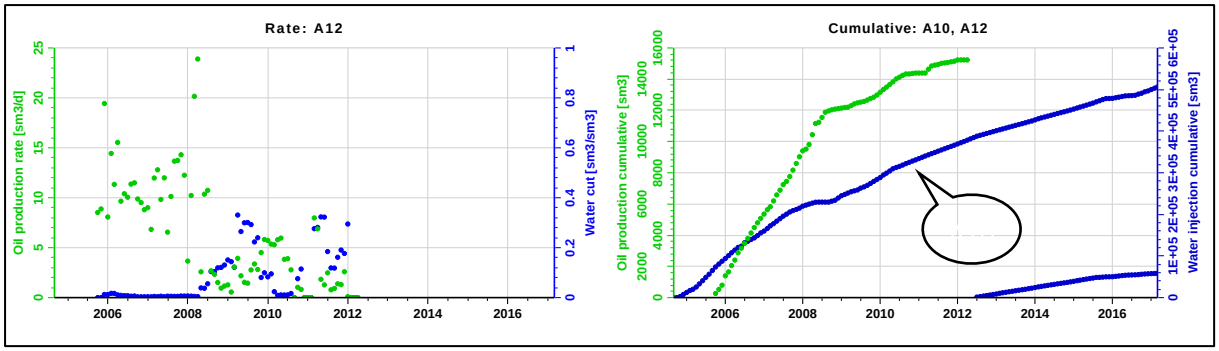


Fig-6: Production and water injection data of well A12 with water injection of A10.

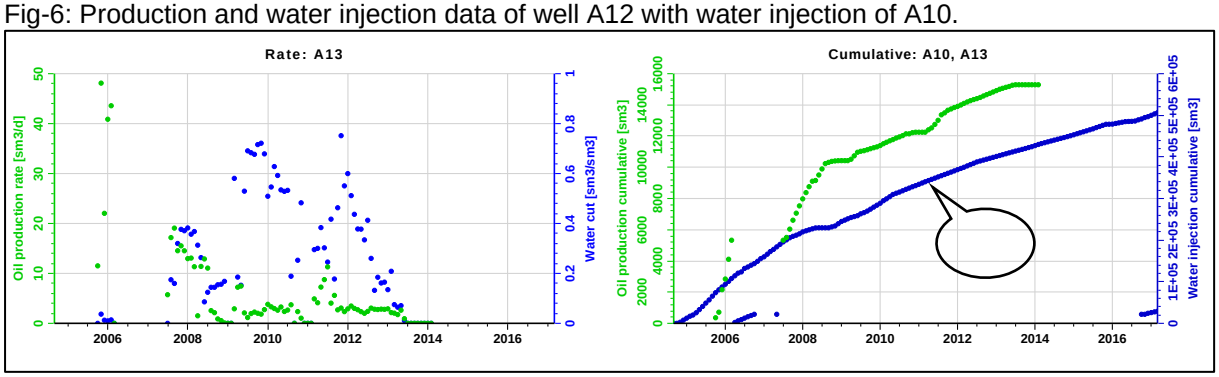


Fig-7: Production and water injection data of well A13 with water injection of A10.

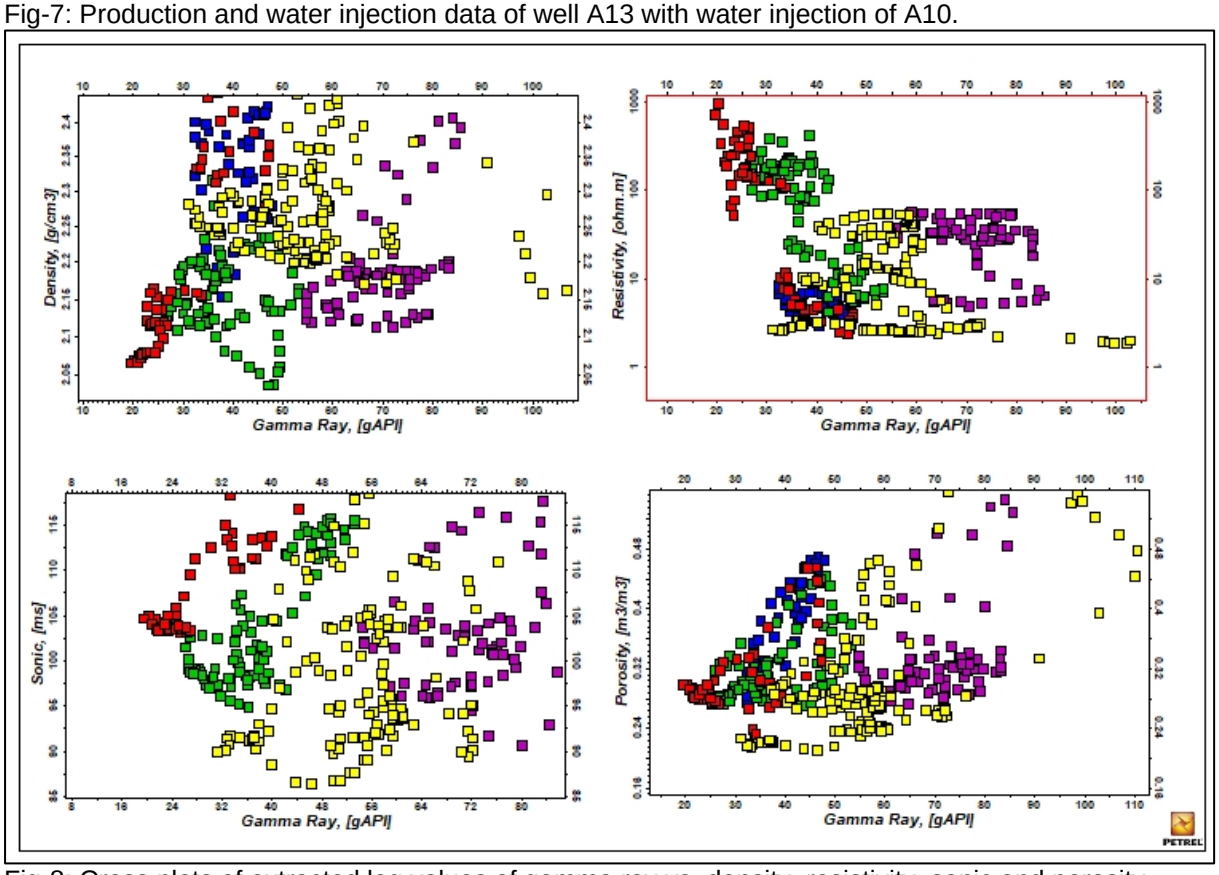


Fig-8: Cross plots of extracted log values of gamma ray vs. density, resistivity, sonic and porosity.

It was observed that effect of water injection is of varying degree in different wells of the block. For one of the nearby wells i.e. A9 the initial pressure was as low as 87 kgf/cm$^2$ which increased to 175 kgf/cm$^2$ indicating pressure support. For the wells A15 on the other hand pressure recorded was only 117 kgf/cm$^2$ despite the nearby injector A1. This large variation in observed pressures of the wells clearly demonstrate the high degree of heterogeneity present in the pool. Figure-8 illustrates the heterogeneity observed in log measurements of different wells. Five representative well were chosen i.e. A1, A2, A6, A12 & A13. It can very well be observed from the cross plots that there is a high

degree of scattering in the data implying high heterogeneity in the reservoir. Porosity histogram of the same five wells along with A10 is shown in fig-9A & 9B. Porosity variation in different wells is evident in the figure.

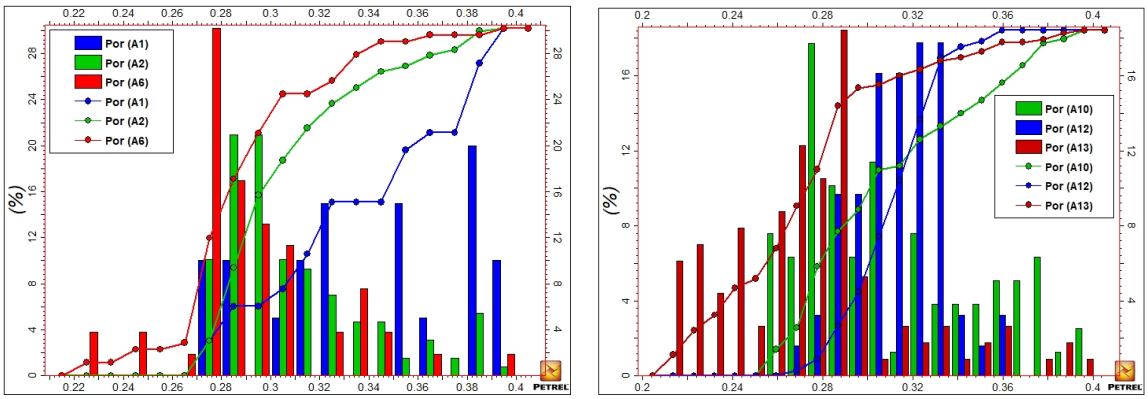


Fig-9A & 9B: Porosity histogram of wells A1, A2 & A6 and wells A10, A12 & A13.

## Block-B

Three wells are completed in this block. The first producing wells in the block is B1. The initial rate of the well was up to 60m$^3$/d which steeply fell to less than 5m$^3$/d. After water injection started in nearby well B2 in Dec-08, the well was rejuvenated and produced up to 20m$^3$/d and later produced with high water cut. Cumulative production from the wells is 47000m$^3$ of oil.

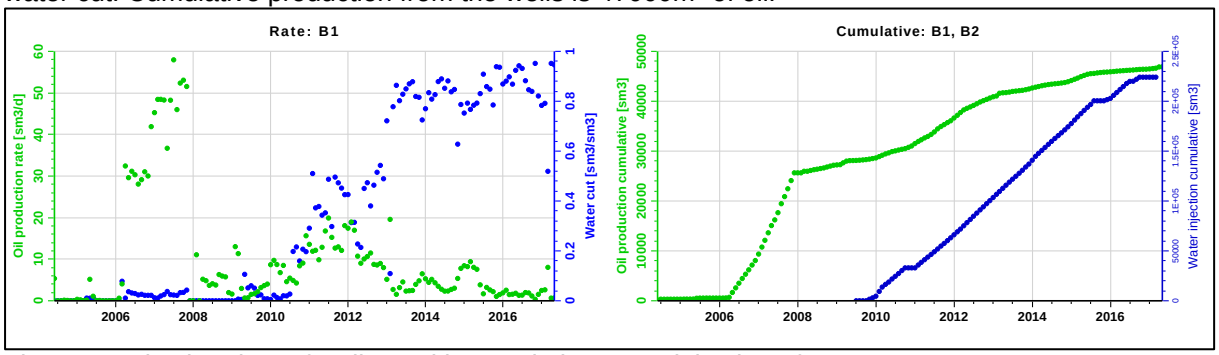


Fig-10: Production data of well B1 with cumulative water injection of B2.

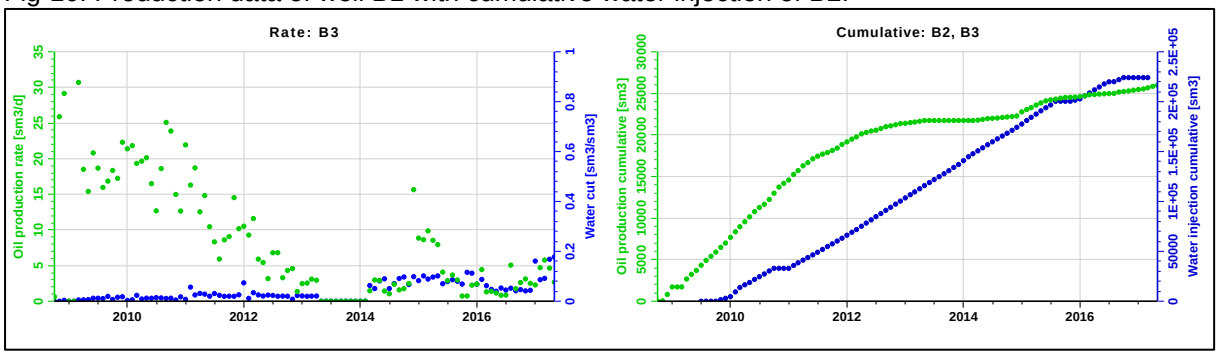


Fig-11: Production data of well B3 with cumulative water injection of B2.

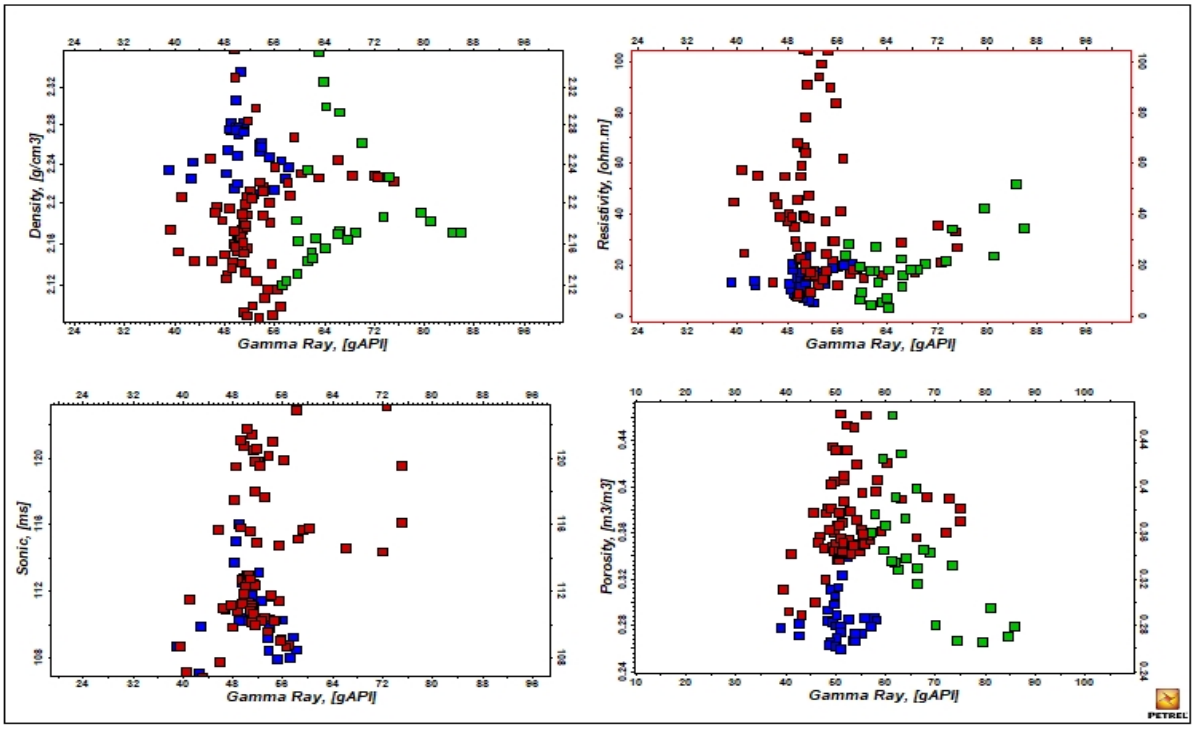


Fig-12: Cross plots of extracted log values of gamma ray vs. density, resistivity, Sonic and porosity.

There is no pressure data available for producer B1. Well B3 show a sharp drop in pressure from 209 kgf/cm$^2$ to 79 kgf/cm$^2$ in four years for a cumulative production of 26000m3 only (fig-10). Effect of water injection can be clearly seen in well B1 as a steep rise in water cut. Well B3 (fig-11) on the other hand has not shown the effect of water injection in the well. This collaborates well with the pressure data of the well (fig-13). Such large variation in nearby producers of a same sand indicates high heterogneity of the reservoir. In figure-12 cross plot of gamma ray vs different logs are shown. High scattering of data is observed in the cross plot indicating heterogeneous reservoir. The porosity histogram (fig-14) also indicate the porosity variation in the three wells. The water injection wells B2 is having porosity mostly in the higher side. B1 on the other hand is dominated by low porosity values whereas B3 is having intermediated distribution of porosity. This heterogeneity is well substantiated by pressure and production data.

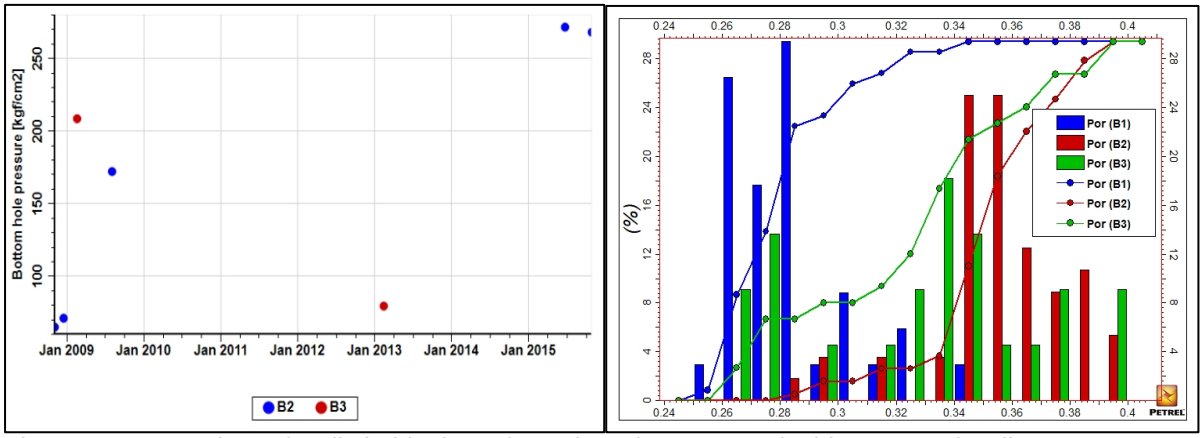


Fig-13: Pressure data of wells in block-B of Sand-1. Fig-14: Porosity histogram of wells B1, B2 & B3.

## Conclusion

From the preceding discussion, it is well established that both the blocks have an inherent heterogeneity which his reflected in the pressures, production and log characteristics of the wells. The preferential movement of injection water to certain production well clearly substantiates the heterogeneity in the reservoir. Large variation in pressure data of different wells pertaining to same block also indicate the heterogeneity of the reservoir. Since the reservoir is in depletion drive water

injection for pressure maintenance is being carried out in both the blocks, but to a limited extent for block-B with only one water injector to support two producers.

The cumulative water injected in block-A is about 1.32MMm$^3$ with an average of 0.22MMm$^3$ of water per well. The total oil produced from this block is 0.85MMm$^3$ with an average oil productivity of 0.057MMm$^3$ per well. In block-B there is only one water injector having cumulative water injection of 0.224MMm$^3$, this has resulted in cumulative oil production of 0.11MMm$^3$ through three wells which comes out to be 0.037MMm$^3$ of oil per well. The higher productivity per well for block-A is attributed to better water injection planned in this block leading to better pressure maintenance despite having high heterogeneity. On the other hand, in block-B, water injection was not sufficient to sustain production from B3, leading to lower recovery from this well. This has led to net lower productivity from this block.

## Acknowledgement

Authors are very thankful to Shri Ashutosh Bhardwaj, ED-HOI, GEOPIC for allowing us to use the data for the study and publish the same. We are also thankful to Shri P.K. Chaudhuri, GGM-Head INTEG for providing us the requisite infrastructure for completing the study successfully. We are thankful to our colleagues who helped us whenever required in any technical matter and project completion.

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

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