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Is Mumbai High a Naturally Fractured Carbonate Reservoir?

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Summary

In this paper a compilation of various studies carried out during different times and through different technologies using a variety of data sets is presented. The objective is to analyze whether the Mumbai High Field is a single porosity or dual porosity carbonate reservoir. The information compiled here includes studies using seismic data, FMS / FMI well logs and cores from various wells besides other expert studies using production, water injection and pressure data and latest available tools. The studies aim at identifying and mapping all faults and fractures. Studies indicate that although some fractures are present in the carbonate reservoirs of the Mumbai High Field, these are not only very few but also are, in general, short in length. It may therefore be concluded that the carbonate reservoir of Mumbai High has no major compartments and is not what is generally regarded as a fractured reservoir.

Introduction

The Mumbai High is a brown field located in the offshore in the Arabian Sea, about 160km WNW of Mumbai city in India. The field was mapped in 1972 and discovered to be oil bearing structure in 1974. It is a doubly plunging asymmetric anticline with a gentle western limb located on a basement high. The eastern limb of this anticline is bound by a set of major down-to-coast faults. The sedimentary sequence is of Tertiary age and major productive reservoirs are within the Miocene carbonate L-II and L-III units.

The main challenges in Mumbai High Field are reservoir heterogeneity and excessive gas production from the large gas cap. Reservoir heterogeneity has complicated the understanding of the water front within the reservoirs making it difficult to locate bypassed oil and optimally distribute water injection for efficient flooding. A set of orthogonal Faults bifurcate the structure into Mumbai High North and Mumbai High South. The fault zone acts as a permeability barrier and restricts fluid movement between these areas. Infill drilling is undertaken to target bypassed oil. This is supported with large scale water injection to maintain reservoir pressure and to flush out more and more oil.

Objectives

The issue of porosity model for Mumbai High has been under active discussion since the discovery of the field. Different theories about the porosity have been projected by experts. One thought is that the reservoir of Mumbai High is a simple primary porosity preserved carbonate whereas some experts think that vugs and solution channels are significant contributors in the porosity / permeability network. There is another school of thought according to whom intense fractures control oil production and water injection. Objective of this paper is to compile and present results of various studies carried out during the last four to five years using different data sets and methods / technologies and analyze the conclusions of all such studies to reach a better understanding.

Methodology

Analysis of results of the following studies has been carried out:

1. Seismic Data – Structural attributes like Dip & Azimuth etc.
2. Seismic Data – Curvature Studies

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3. FMS/FMI logs of about 26 wells
4. Core Data of about 28 wells
5. Compartmentalization Studies

The results of various studies have been compiled and inferences have been made which are briefly discussed as follows.

Results

Structural interpretation of seismic data aided by attributes like dip, azimuth, cosine of phase and rugosity etc. were carried out. Faults seen on seismic data have been mapped and a fault map at the top of L-III is shown below:

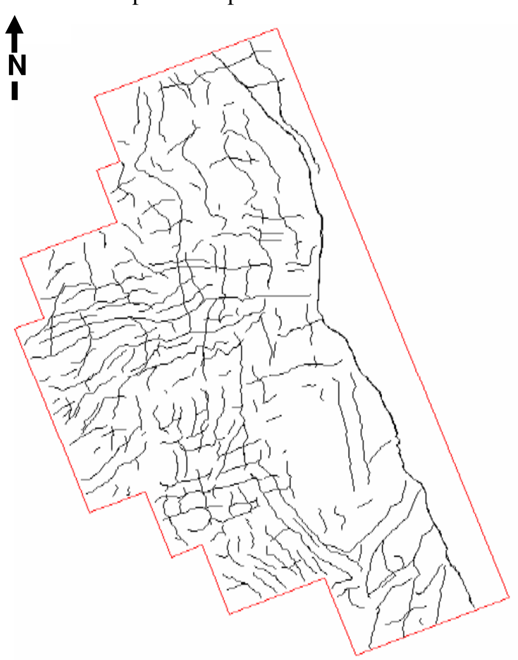

Fig.-1: Fault map at top of L-III

The fault map (Fig. – 1) shows all seismically visible faults. Curvature studies were undertaken during 2007 on pilot scale covering areas of Mumbai High North and South including the permeability barrier between the two areas. The result is shown in fig. – 2.

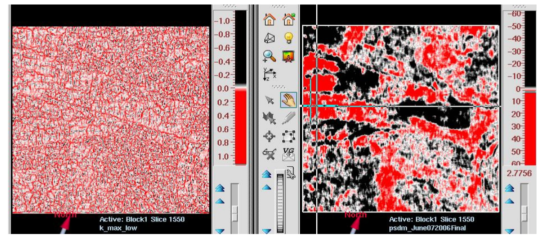

Fig.-2 : Seismic data and curvature attribute - It may be seen that small magnitude faults have become clear which are difficult to see on normal seismic display.

The curvature analysis did bring out even those small magnitude faults and fractures which are normally not observed on the conventional display. All such faults and fractures have been included in the fault map shown in fig.-1 and it may be noted that the fault/fracture density is not high.

Fracture study on FMS/FMI logs of 26 wells in L-III reservoir reveals that fracture density is too less compared to dissolution surfaces. In fact, correlation of mud loss data indicates that heavy mud losses occurred in the wells having high dissolution surfaces but not higher fracture densities. The comparison of production data with the fracture densities does not show any correlation. Fig.-3 below shows an image where dissolution surfaces and fractures are identified on FMS/FMI data.

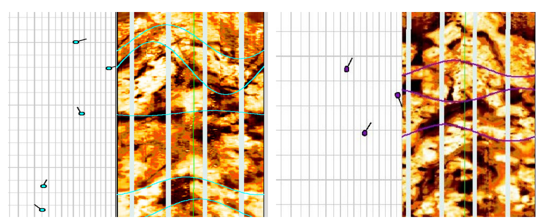

Fig.-3: Showing interpreted dissolution surface and fracture on FMI data.

Core data analysis was done on a comprehensive basis for all the cores available (28 wells, 122 numbers of cores measuring 1365m in length).

Examples of vuggy porosity (fig.-4) and fractures (figs.-5 and 6) from the cores within L-III reservoir have been displayed below:

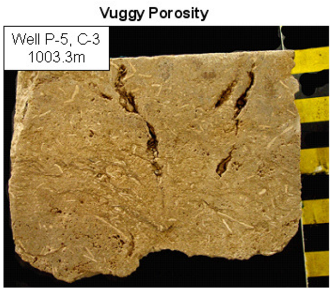

Fig.-4: A core sample showing open vugs,

Fig.-5: Presence of natural fractures in core

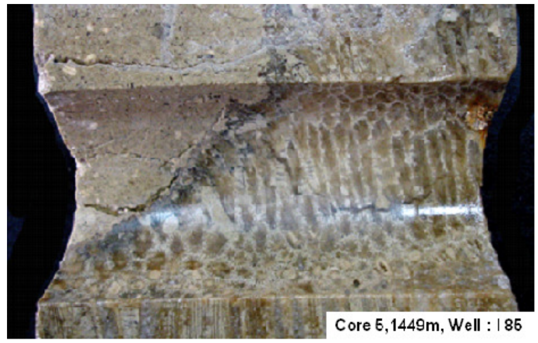

Fig.-6: Showing partially healed fracture in a core of MH North

Reservoir compartmentalization analysis and modeling of reservoir inhomogeneity studies were carried out using multidisciplinary approach. It consisted of
(a) Analysis of well interaction by using production and injection time series;
(b) Layer wise mapping and classification of reservoir properties
(c) Classification and conversion of seismic properties and
(d) Petrophysical analysis and log interpretation.

Results derived by using the above stated complex analysis were then integrated into a conceptual model which explains features of reservoir performance. One of the objectives of the study was elaboration of flow barriers position and reservoir connectivity analysis through Reservoir Compartmentalization Analysis.

One of the conclusions of this work was, "Reservoir properties impose most influence on fluid infiltration; effect of fracture conduits is much less".

Conclusions

All the faults and fractures observable on seismic data have been mapped. It is observed that, on an average, the faults / fractures occur in the direction of dip at an interval of about 2.0 – 2.5 Km. Production and reservoir pressure data indicate that there is no significant flow barrier due to the presence of these faults and therefore it may be inferred that there are no major compartments within the reservoir.

From the Curvature studies carried out on seismic data, only a few lineaments could be brought out, however, they could not be correlated to the fracture data observed through FMS/FMI. It is difficult to identify the specific lineament on curvature map which created the fracture as observed in FMS/FMI data. Therefore, the lineaments observed on curvature studies may or may not represent fractures.

From the FMS/FMI studies it has been concluded that the fracture density and apertures are too less to contribute in the production. The production behaviour also suggests that the fractures are not the factors for fluid movement.

From core studies, it has been concluded that

(i) The vugs are not common in cut cores, are typically in the range 0 – 10 % and on visual estimates, the average is 3 %.

(ii) Fractures are not common in cores, are less than 5 cm in length and are partially open.

(iii) Mainly short, gash fractures, commonly associated with stylolites are observed on the cores.

(iv) Few typical tectonic fractures (long, continuous) are present.

(v) This is not what is regarded as a "fractured reservoir".

The reservoir compartmentalization studies indicate that fractures are not providing any significant flow paths for fluid movement and therefore not controlling the production from Mumbai High Field.

From the above conclusions it may safely be stated that the Mumbai High Field is not a naturally fractured carbonate reservoir.

Acknowledgments

This paper is a compilation of studies carried out during the last five years by experts working for different agencies. Contributions of all those experts are thankfully acknowledged. The author is thankful to Shri SK Verma, GM-SSM, MH Asset and Shri Apurba Saha, ED_Asset Manager, Mumbai High for constant encouragement and facilities provided for this work. Sincere thanks and deep gratitude are due to the ONGC management for permitting the presentation and publication of the paper.

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