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Understanding Complex flow behavior through Reservoir Pressure Depletion Trend and core based flow zone indicators.

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Summary

Reservoir pressure is a fundamental property of the reservoir and its depletion provides an insight in to the reservoir dynamics and drainage pattern. Reservoirs under geological condition in general have more preferred drainage path such as long axis or the fold axis compared to its orthogonal trend. This is expected as the fold axis follows a stress trend which is related to the facies distribution along and perpendicular to this axis. Post production pressure measurement at different part of the reservoir against zone of production can provide valuable data to understand the differential reservoir drainage. In one of the fields in western offshore of India, MDT pressures in different wells drilled at different times during field production provides valuable information to the drainage pattern and the depletion trend along various direction gives insight into the differential drainage as result of possible different flow zones . The pressure trends in turn provide an important input for reservoir simulation.

Keywords*: MDT Pressure, Reservoir Pressure Depletion, Flow zones*

Introduction

Z Structure in Paleogene shelf margin of Mumbai offshore is oil bearing in the Early Miocene carbonate section. This shallow marine Early Miocene Carbonate Sequence represents cyclic sedimentation resulting from frequent sea level fluctuations. Each Sedimentary cycle is followed by a minor hiatus resulting in sub-aerial exposure responsible for development of porosity. Most of the porosities are secondary, in the form of vugs, molds, and solution channels created in vadose zone.

In Z area porous and nonporous sub-layers are developed due to periodic exposure of shoal-reef complex. Reservoirs are developed within an Early to Middle Miocene shelf margin shoal-reef complex setting in secondarily developed porous limestone units. Z-E-12 is the northernmost well of Z (South) field separated from the main field by a NS trending fault. The hydrocarbon bearing zones of Z South were divided into five pay zones. These five pay zones of Z (South) field are within the Early Miocene limestone section. These were designated as Pay-1 to Pay5 (Fig.1). These pays are characterized by very high permeability from tens of milli Darcy to few Darcies. Out of the 5 pays, Pay-II and Pay-IV have been prolific producers. Pay-V has a known OWC and has been put on controlled production due to proximity to aquifer even though this pay shows best permeability behavior from various studies.

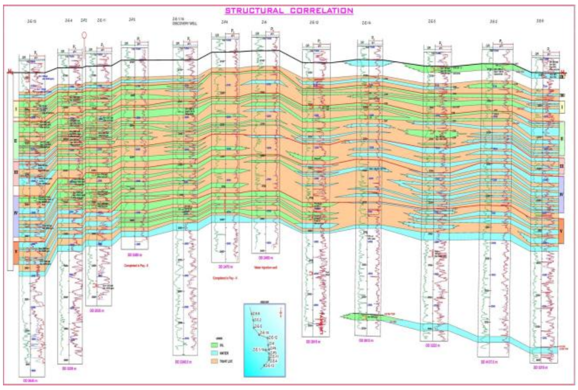

Fig.1 Structural Correlation of Pay zones in Z-Field.

Historical Perspective

Field Z was discovered in 1976. 13 exploratory wells were drilled on the structure till 1996 and the field was

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delineated. Based on field development report first platform well Z-P3 was drilled in 2006. Field was put on production in February, 2006. Subsequently, over the next three years, 5 more producers and 6 injectors were drilled from the platform(Fig.2).

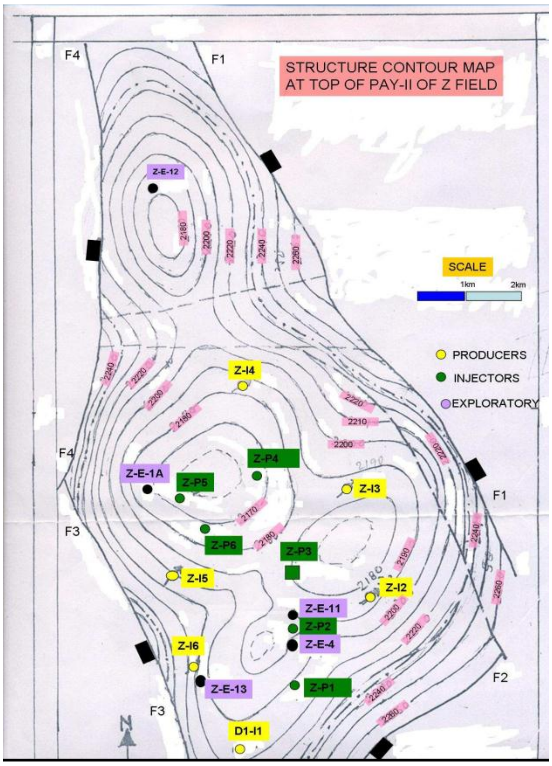

Fig.2 Structure contour map on Pay-II.

All injectors on drilling showed substantial oil column against the pay zones. Hence all injectors except Z-I3 were completed as producers for an early production, with a plan to convert them in to injectors subsequently. Extensive data acquisition including MDT in almost all wells, FMI in few of the key wells, PLT over three campaigns at different times has helped in getting an insight in to the complexity both in static facies variation to more pronounced differential flow behavior. An attempt has been made to address some of these complex issues through an integration of various data.

Pressure Studies Through MDT

In the very first platform well Z-P3, MDT pressure profile showed a normal hydrostatic pressure regime. (Fig.3).

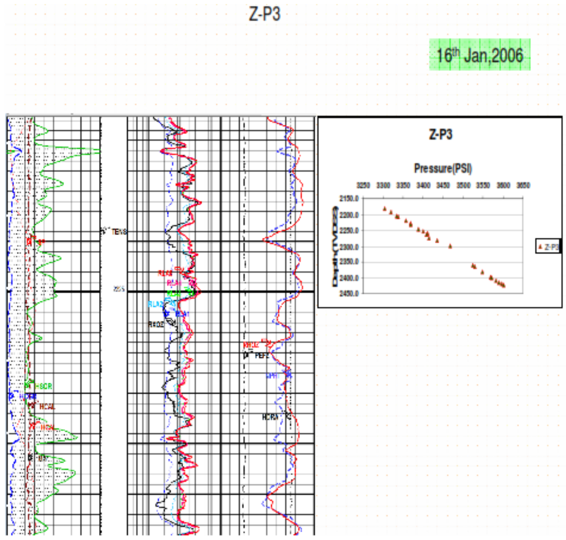

Fig3. Log Profile against Pay-II and MDT Pressure Plot for Well: Z-P3

MDT in later wells showed gradual depletion against the major producers Pay-II and Pay-IV (Fig4).

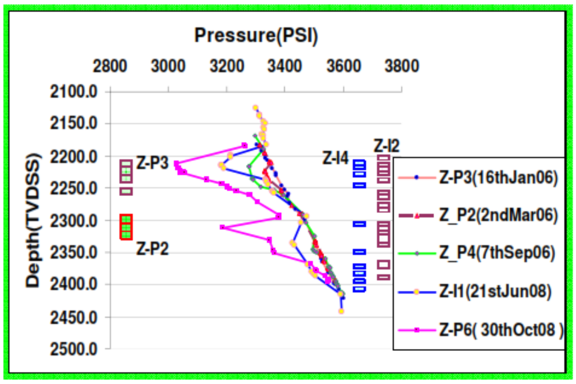

Fig4. MDT Pressure Comparison

Being a very low GOR (~ 30), undersaturated reservoir, the depletion was expected to be even more than what the MDT pressures indicated. The possibility could be a very mild aquifer support from the edges. The depletion trend was analyzed keeping in view the distribution of producers vis-à-vis injectors. A substantial difference is observed in the depletion trend for the producers which are along the crest as against the injectors which are on the flanks. Faster depletion is observed along the crest compared to a slower depletion along the flanks (Fig.5).

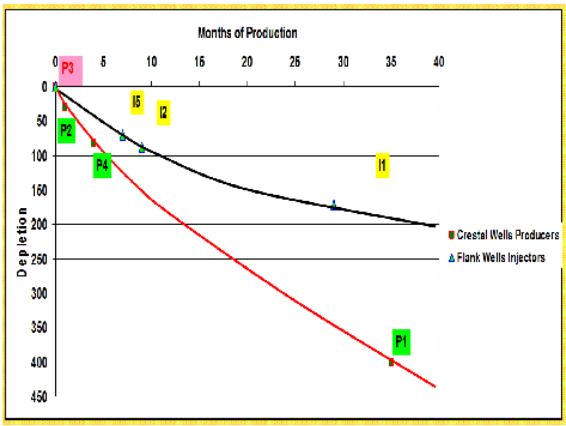

Fig.5 Differential Depletion Trend for Producers and Injectors for Z-Field.

This differential depletion has a significant role in bringing out the likely preferential drainage pattern, an issue which needs to be addressed both in the static model and in simulation.

PLT Studies

A number of extensive PLT campaigns have rendered extremely valuable information about the reservoir behavior. The perforation policy has envisaged paywise perforation and completion for the producer wells, whereas for the injectors all payzones have been perforated simultaneously and completed in all zones. The PLT against these wells (Fig6 &7) show strikingly different flow behavior than expected from conventional log analysis. Zones with rather inferior petrophysical properties contribute substantially more than zones with better properties. An elaborate PLT and MDT study by Sunil Chaudhary et.al has brought out this anomalous behavior quite in detail. The possible reason for this differential flow behavior is likely to be in distinctivity of the zones in terms of their flow character.

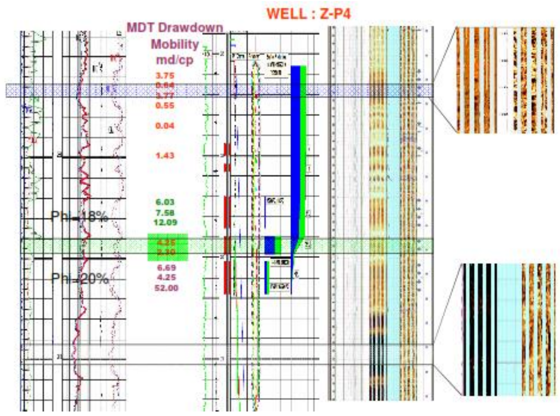

Fig.6 Composite plot of PLT, MDT, FMI and Conventional Log for Well: Z-P4

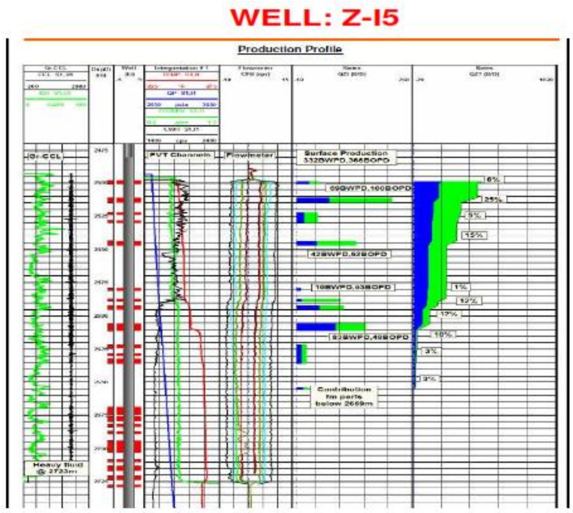

Fig.7 Flow contributions of Pays through PLT for well: Z- I5

Flow Zone Indicators

Pore level property of flow behavior allows one to look in to differential flow patterns in different zones. The static property of porosity need not necessarily can bring out the flow behavior of a rock. In this context, derived parameters such as Reservoir Quality Index (RQI) and Flow Zone Indicators (FZI) can be used for better description of flow zones. Extensive conventional core data from wells: Z-E-4 and Z-E-13 has been used for this study. The study has brought out 7 DRTs (Fig.8), signifying 7 distinct flow units.

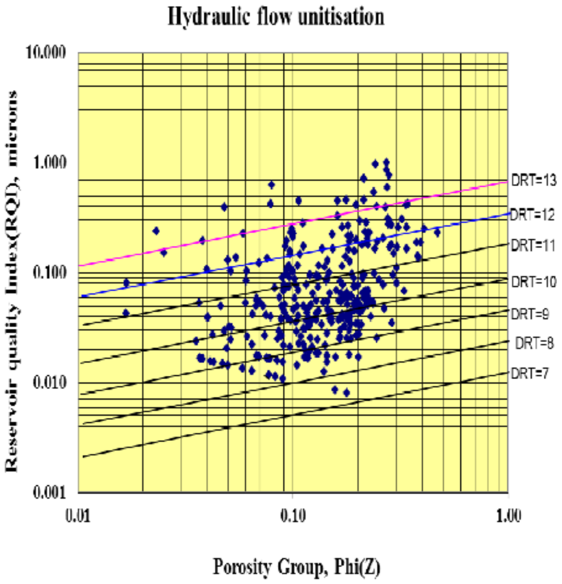

Fig.8 Hydraulic Flow Unitisation through DRT

Using normalized porosities, these DRTs have been used to generate 7 Hydraulic units (HU) with each one having its unique K-Φ relationship (Fig.9).

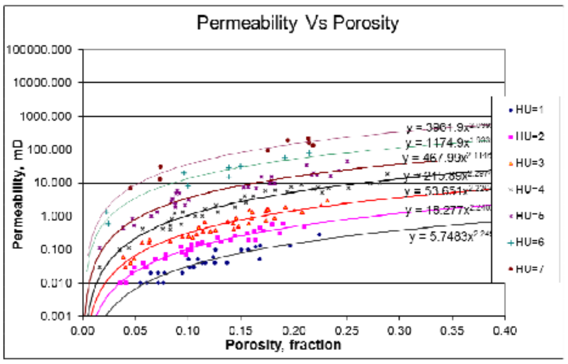

Fig.9 Porosity–Permeability Plot with Hydraulic Unitisation,

This characterization defines a rock with respect to its intrinsic flow character. However, to bring FZI to reservoir scale, each FZI needs to be linked to various log parameters through transforms. Using these transforms, each point on log domain can have its FZI value along with its other properties like porosity and saturation. Propagating this FZI property into the static model will finally bring out the FZI heterogeneity in the reservoir, which can provide a unique platform for a realistic reservoir simulation, which can explain the differential flow patterns as has been seen in field Z.

Conclusions

Carbonates are known for their heterogeneous behavior both in facies distribution and flow pattern. The challenge is to capture these in to the static model. Field Z in Western offshore of India is a carbonate platform structure. Both pressure depletion trend and production logging data brings out its heterogeneous nature. Log based porosity and shaliness is not sufficient enough to address these complex flow behaviors. 7 distinct flow units with their characteristic K-Φ relationships have been identified through RQI(Reservoir Quality Index) and FZI (Flow Zone Indicators) using the extensive core data available in the field. These derived properties once propagated in to static geological model could answer the differential flow behavior as the one observed in field Z. In order to bring FZI to reservoir scale, it is being attempted to link these FZIs to various log responses using Multivariate correlations and generating unique transforms. Once the work is complete, it will be possible to generate FZI for every data point on log scale, which will be one step behind propagating FZIs like a log property in to the Geological model to address the hitherto unanswered differential flow patterns.

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