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Efficacy of Seismic Attributes for Reservoir Characterization.

- *A Case Study in Mumbai High field, ONGC, INDIA.*

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ABSTRACT

Mumbai High, the largest oil field is situated on the west coast of India. The field has been on production for four decades. For production maintenance various development schemes were practiced in this field. Till now the major emphasis was judicious planning of infill drilling and side track of existing wells with optimum spacing. As sufficient wells have been drilled, less ambiguity in placement of new or side track wells was experienced. But as the field is maturing new challenge is to place step out locations from new platforms. In this view, the area in south western flanks of the Mumbai High South field has been studied in detail.

For the development of this western periphery some exploratory wells were drilled and for development of the area further west of these exploratory wells PSDM/PSTM seismic data attributes are used to decide proper placement of locations. As per the present geological model about the reservoir for western flank of Mumbai high south field, all layers of L-III reservoir unit which is around 60m thick with limestone shale alterations are water bearing except the top most limestone layer which is 6-10m thick and above inferred OWC.

In this study, the reflection strength of seismic PSDM data was analyzed with back drop of geologic setup at the time of deposition. The reflectivity was correlated with porosity development which was further confirmed by extraction of sweetness attribute on PSTM volume and was statistically in accordance with adjacent wells.

On this basis a facies distribution map was prepared and accordingly wells placement was planned in favorable facies area. Two subsea wells X & Y having drain hole of 500m and new locations C1 to C4 were proposed from platform C after the study.

The paper highlights the inherent strength of seismic data in areas where there is no well control; an attempt has been made for effective use of seismic attribute and reflection strength in understanding the structural variations and reservoir facies distribution for placement of development wells in Mumbai high field and thus enabling in planning of development strategy

Introduction

As the known oil fields becomes more mature and remaining targets are better concealed and/or complicated, it is important to locate the suitable facies, its extent in the known reservoir and relationship with the adjacent layers. In recent years, the E & P industry has been greatly benefited from the application of 3-D seismic data. This technology has increased our capability to accurately plan economically viable locations. Seismic attributes are defined as a mathematical transform of the seismic trace to predict petro-physical properties. Without seismic data, geoscientists need to measure physical properties using well logs and/or core, and then interpolate between wells. Seismic data is the composite response of lithology, porosity development, fluid, bed stacking pattern, bed thickness and other geological factors. As such, seismic data is incredibly rich in amplitude, frequency, phase, and geometry and texture information of sub-surface. Geoscientists always look for Geo-bodies with favorable reservoir properties. Seismic attributes are one of the many tools used to help select strategic placement of horizontal wells.

The discussion in this paper is for Mumbai High carbonate reservoir (Fig: 1). The paper will provide a description of terminology , reflection strength and sweetness attribute , as well as provide the interpreter a methodology for accurate placement of horizontal wells.

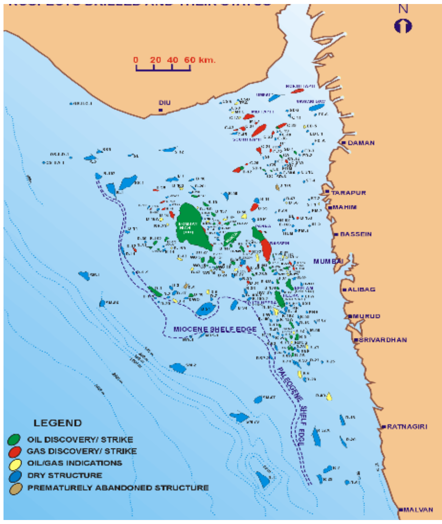

Fig 1 - Location Map of Mumbai High

Geology

The Mumbai Offshore basin is located on the western Indian shelf. The field is geologically unique and is located on a regional high. It is a gentle westward dipping doubly plunging anticline, bounded by a major fault in the eastern margin of the field. It has a vertical closure of around 250 meters at the basement level and covers an area of about 1800 sq.km. The positive relief of Basement High is sustained upto Miocene times. The main oil/gas reservoirs in this field are L-II and L-III whereas the other 5 reservoirs identified are only marginally hydrocarbon bearing. The L-III reservoir is thin bedded limestone reservoir separated by shale streaks with large scale heterogeneity .The main producing L-III reservoir is in turn divided into 10 sub layers having thickness of around 4m to 6m (Fig:2). The lithology includes Packstones, wacke stones & mudstones as the prime constituents with patchy dolomatisation. Vugs & channels are the main porosity type with wide variation in porosity and permeability. The sedimentary sequence in Mumbai High from deep to shallower lithofacies can be divided into Basal Clastics, Limestone with shale alternations and shale /clay/claystone. Basal Clastics are deposited over the basement. These are mostly fluvial in origin. These sediments belong to Paleocene to early Oligocene. In northern part the field the basement is mostly basaltic in nature where as in South it consists of fractured/weathered, gneiss, schist & basalt as basement.

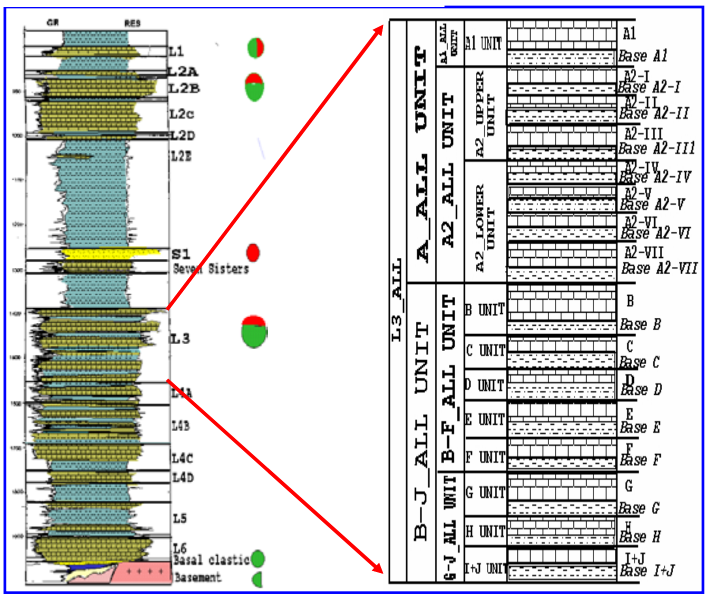

Fig 2 - Generalized stratigraphy of L-III reservoir Mumbai High

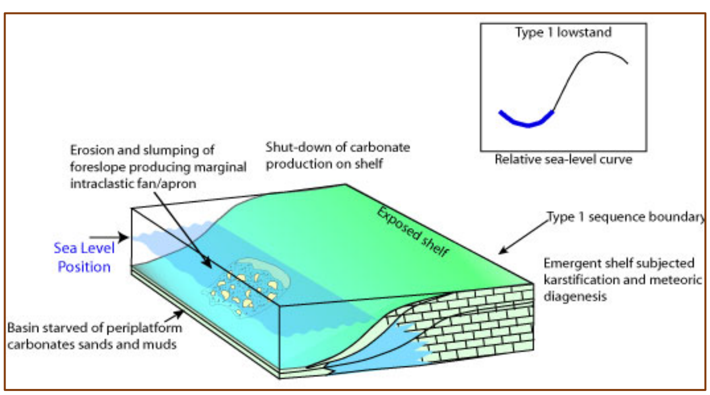

Fig 3 –Lowstand (carbonates)

Historical background

Conventional seismic reflection data are band-limited to 125 Hz with the typical sample rate of 4ms or 2ms, although the useful signal bandwidth usually does not exceed the range of approximately 10-60 Hz. The practical band limitation is a consequence of the geometry of the recording parameters, the sample rate, source energy, and the elastic response and dampening of the sub-surface. Compared to well logs, seismic data have limited bandwidth on low and high ends. As acoustic impedance (AI) is the product of rock density and P-wave velocity. This means that AI is a rock property and not an interface property. This variation in acoustic impedance, a rock parameter is affected by the type of lithology, porosity, fluids contents, depth, pressure and temperature.

Therefore, variations in reflectivity and different responses in sweetness attributes because of changes in acoustic impedance can be used as an indicator of lithology, porosity, and also for lithology mapping, and reservoir character quantification. The amplitude of the reflection is proportional to the impedance contrast of the layers, greater the impedance contrast, greater is the reflection amplitude.

Methodology

In this paper authors have presented detailed work done which includes one to one correlation of variation in seismic amplitudes to the geology at the time of deposition, further the strength of reflection strength was confirmed on sweetness attribute derived on PSTM volume , thus strengthening the observation that reflection intensity shown on PSDM seismic correlates well with the porosity development. If we consider a lowstands model of carbonates (Fig: 3), it is observed that the carbonates below the low stands remained submerged and never got time to get leached by meteoric fluids. This area can be considered on western side of the marked dotted line in Fig.5.

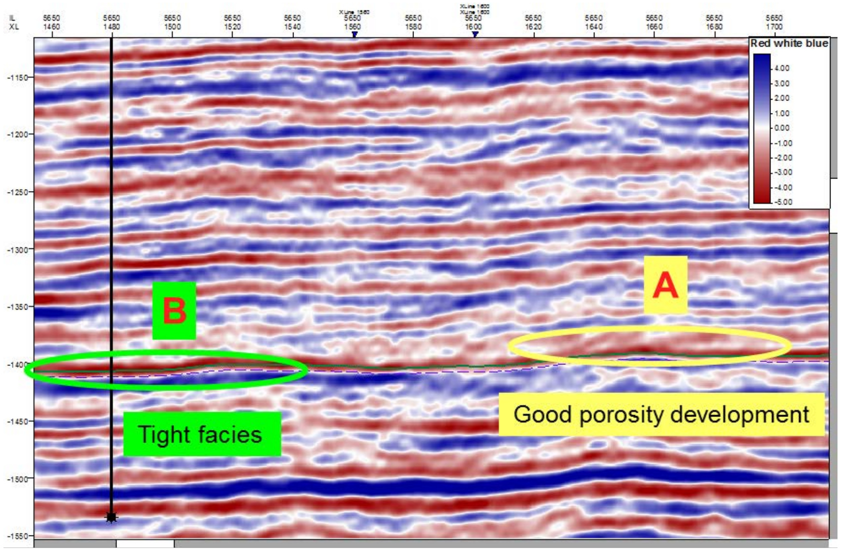

Fig 4 –Seismic section showing increase in reflection amplitude from A to B

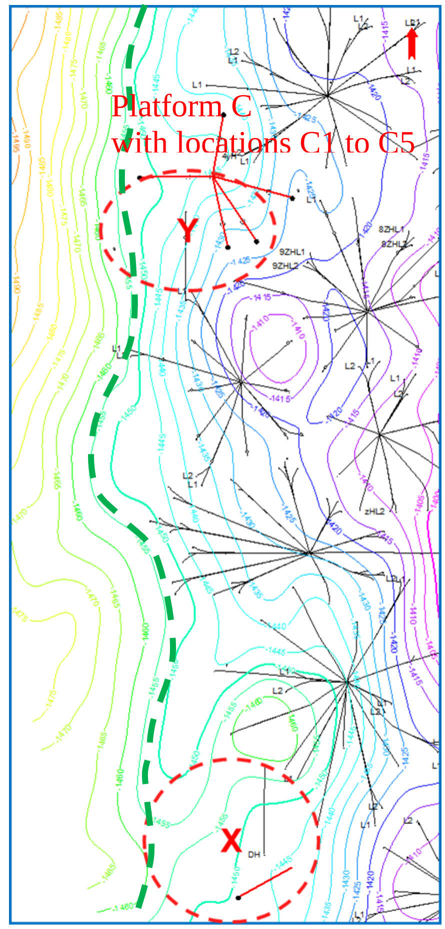

Fig 5 –Location Map (Area of study X & Y)

Case study

Mumbai High is a prolific producer of hydrocarbons from the Miocene carbonate reservoir. The carbonate reservoir is highly heterogeneous and therefore creates lot of uncertainties and lateral variations along the drain hole. A slew of wells have been already drilled and a few locations are still left un-exploited. The present locations X and Y under discussion were to be drilled as a horizontal wells with 500m drain hole length and new conventional wells from new platform .The landing point was finalized on the basis of the study that as we move from east to west the structure dips considerably and there is perceptible change in porosity development. The seismic cross-section (Fig.4) along East to West Inline direction clearly shows the increase in reflection strength from area A

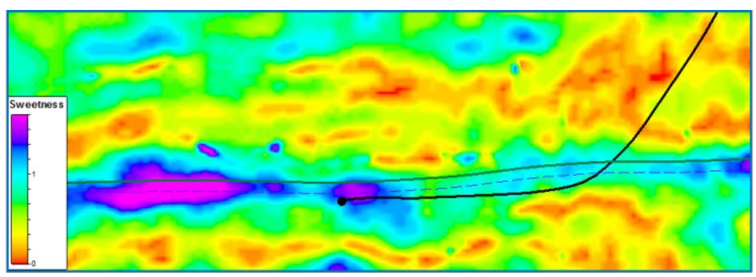

Fig 6 –Drain hole Y of 500m goes from good to tight facies from toe to heel (sweetness attribute)

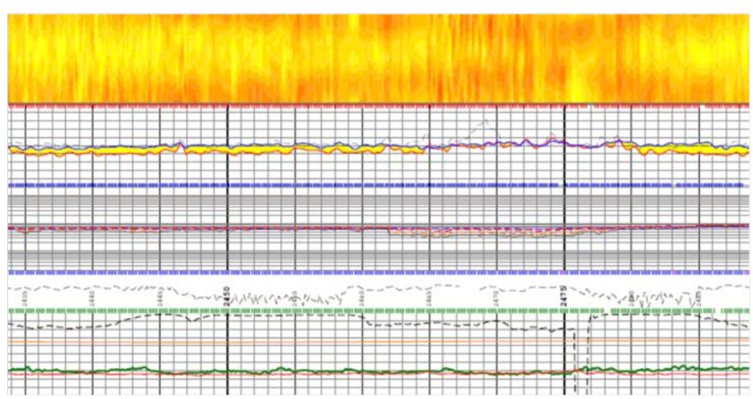

Fig 7 –Log motif of well X of 500m goes from good to tight facies from toe to heel (sweetness attribute) having better porosity development due to exposure to meteoric diagenesis than to area B having tight facies as it was well below Low stands (Fig.3) and did not developed porosity ,thus showing good reflection strength. Two drain holes were planned at location X & Y. The drain hole for location Y which was placed well below L-III marker as shown in Fig.6 with sweetness attribute plotted along the well section, as the formation dips and the areas below lowstands have not developed porosity and shows tight facies at the end of drain hole ,while for location X the drain hole falls well above the lowstands and have sufficient porosity development which is clearly evident on the LWD logs as in Fig-7,about 90% of the drain hole of location X was placed successfully in favorable facies area. Thus further planning and development of the field would be done considering the porosity development and its signature on seismic volumes.

Conclusions

The one to one correlation of variation in seismic amplitudes to the geology at the time of deposition, further the correlation of reflection strength with sweetness attribute derived on PSTM volume, thus strengthening the observation that reflection intensity shown on PSDM seismic correlates well with the porosity development. The lowstands and highstands model of carbonates explains the variation in porosity development; it is observed that the carbonates below the low stands remained submerged and never got time to get leached by meteoric fluids while above lowstands the limestone was exposed to meteoric diagenesis and developed good facies for hydrocarbon accumulation.

The method so adopted met with an amazing success in the placement of horizontal well in the Mumbai High field. A number of new wells from new platform are released considering the study and further subsea horizontal well planned in order to exploit the hydrocarbon as early as possible.

References and Suggested reading

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