Determination of 'Carbonate Line' for Mumbai High Field

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Abstract :

Carbonate reservoir characterization using seismic amplitude inversion, which generates acoustic impedance, lamda-rho and mu-rho, is very much effective tool now-a-days. Shear wave and P-wave logs are pre-requisite for amplitude inversion. Non-availability of shear wave log is the main hindrance to get information about lithology and petro-physical properties accurately. General practice is to calculate S-wave log from P-wave log through Castagna's mud-rock line relationship.

Mumbai High is a major oil field in India. The main reservoirs (LII & LIII) are carbonates. More than 900 wells have been drilled and P-wave sonic log is available for about 60 wells. It is well known that Castagna's relationship is not valid for carbonate reservoirs. Until recently, these valuable sonic data could not be used for S-wave inversion for lack of correct relationship between P-wave and S-wave logs. Recent acquisition of dipole sonic logs in two wells that sampled the reservoir zones produces information about the relationship of P-wave and S-wave velocities.

In this work authors tried to establish a relationship between P-wave and S-wave logs by cross-plotting P-wave and S-wave velocities within the carbonate reservoirs. We find that relationship is linear and, similar to Castagna's definition; we call this linear relationship as the "Carbonate Line" for Mumbai High Field. It can be seen that the Carbonate Line deviates from the clastic mud-rock line with a slope significantly less than that of clastic rocks.

The new Carbonate Line for Mumbai High Field enables to use the P-wave log data of about 60 wells for seismic amplitude inversion of S-wave and thereby, eventually to generate lamda-rho, mu-rho volume for the whole of Mumbai High Field to characterize the carbonate reservoirs confidently; although the definition of the "Carbonate Line" is likely to improve with the availability of more number of shear wave logs.

Keywords : Cross-plot, Amplitude Inversion, Impedance, Incompressibility-Density (lamda-rho), Rigidity-Density (mu-rho)

Introduction

Mumbai High is a major oil field in India. It is located in western offshore of India and accounts for about 50% of India's oil production. It is gentle westward-dipping anticline and bounded by a major fault trending NNW-SSE along the eastern margin of the field. Carbonates are the main sedimentary rock in this field and range from late-Oligocene to mid-Miocene in geologic age. Large oil and gas reserves exist in early to mid Miocene carbonate formations. The two important multi-layer carbonate reservoirs in Mumbai High are L-III and L-II. The clastic reservoir S-I sand is free gas bearing and lies between L-III and L-II reservoirs. More than 900 wells have been drilled and till date the detailed heterogeneity of the reservoir is unknown. Presently, most of the wells being drilled are horizontal. Therefore, for drilling a successful well, it is essential to know the properties of carbonate reservoir more accurately using seismic amplitude inversion, which generates acoustic impedance, lamda-rho and mu-rho. It is an effective tool available today to identify the potential reservoir.

To generate above mentioned attributes from seismic data both P-wave and S-wave logs are necessary. In Mumbai High field P-wave sonic log has been recorded in about 60 wells. It is a general practice to generate S-wave log from P-wave log by using Castagna's mud-rock line relationship. But this relationship is not valid in carbonate reservoir (Yongyi Li et al., 2003). Until recently, these valuable sonic data could not be properly utilized for S-wave inversion due to lack of appropriate relationship between P-wave and S-wave velocities.

Reservoir Identification

Recently acquired dipole sonic logs in two wells that sampled the reservoir zones provide valuable information regarding the relationship between the P- and S-wave velocity. It is found that the cross-plots between P-wave and S-wave impedances of L-III reservoir generated from well logs can identify the pay-carbonate zones.

Figure-1 and Figure-2 depict that some separation of pay-carbonates can be seen at seismic resolution for Well No-1 and Well No-2 respectively. It prompted us to generate P-wave and S-wave impedance volumes from existing seismic data. S-wave log, which was unavailable until recently, is a pre-requisite to generate Shear-wave impedance as well as lamda-rho and mu-rho volume from seismic data. To generate S-wave log from existing P-wave log a suitable relationship is required for carbonate reservoir.

Determination of Carbonate Line

To generate S-wave log from existing P-wave log a suitable relationship is required for carbonate reservoir. Figure-3 and Figure-4 show a set of dipole sonic logs (Vp in blue color and Vs in red color), gamma ray and corresponding

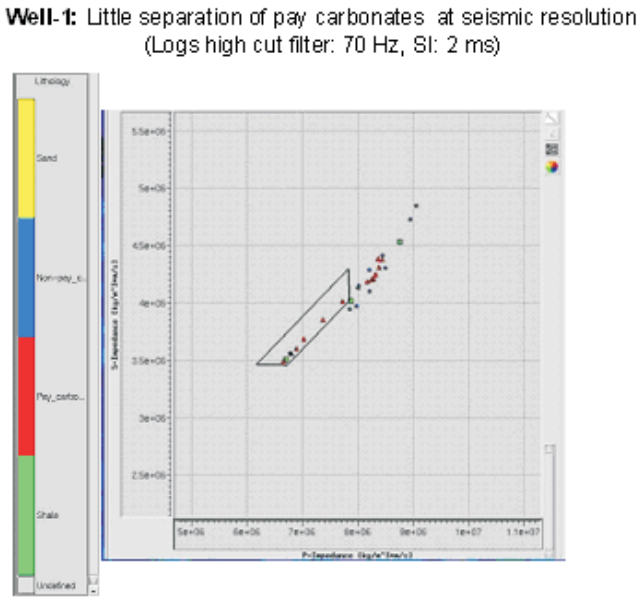

Fig.1 : Cross-plot between P-Impedance and S-impedance.

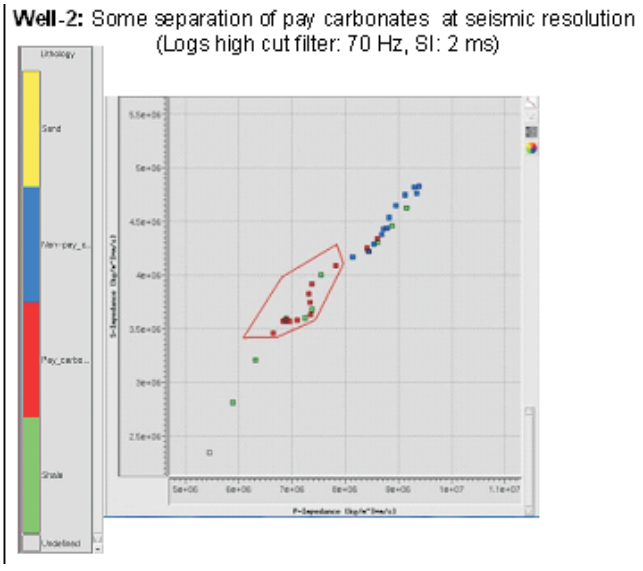

Fig.2 : Cross-plot between P-Impedance and S-impedance.

lithology for L-III reservoir of Well No-1 and Well No-2 respectively.

For these typical log data sets, the carbonate rocks mainly consist of oil and water saturated lime-stone. As the available P-wave logs have mostly been recorded in both oil and water saturated zones of the L-III reservoir, a cross-plot between P-wave and S-wave velocity of L-III has been generated for the interval 1355-1427 m which is predominantly carbonate.

Figure-5 depicts the cross-plot of a P-and S-wave velocities for both the wells and a line with relationship of Vs=0.46896Vp + 199.634 is well fitted to the carbonate lithology cluster with correlation co-efficient of 0.8. We call this line as 'Carbonate Line' for Mumbai High Field which has lesser

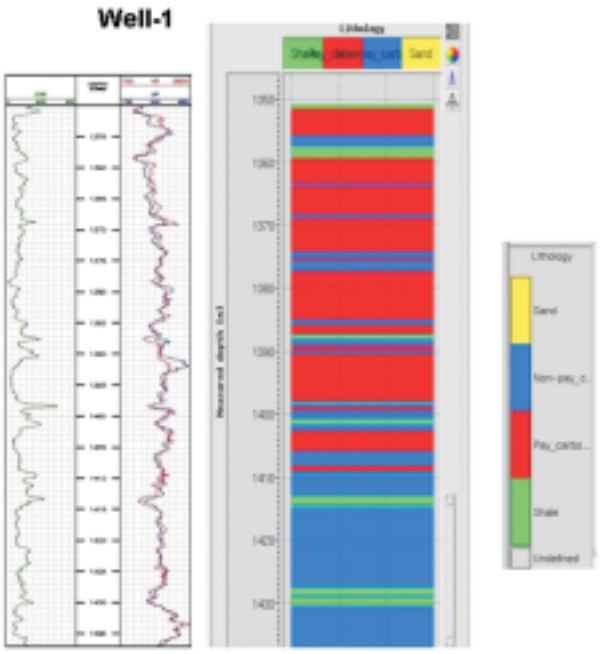

Fig.3 : Dual Sonic, Gamma ray and Lithology of L-III reservoir of well-1

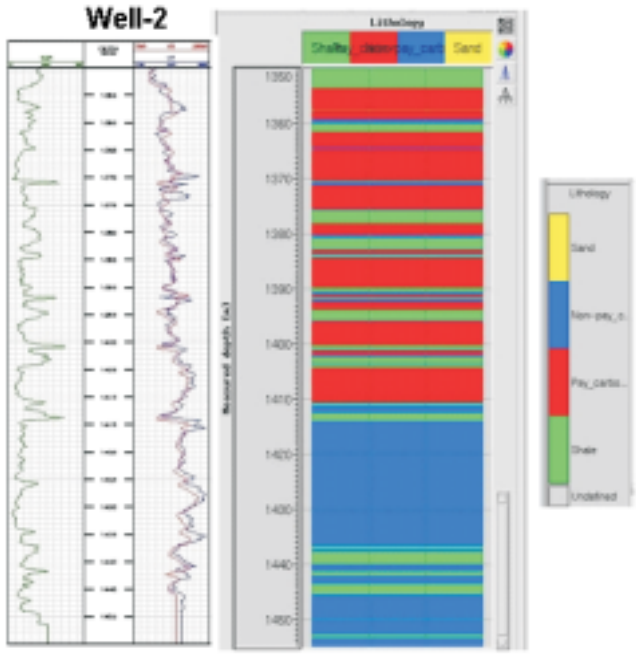

Fig.4 : Dual sonic, Gamma ray and Lithology of L-III reserovir of Well-2

slope than Castagna's mud-rock relationship Vs=0.862Vp – 1172.4

The Carbonate Line thus derived enables to use the P-wave log data of about 60 wells for seismic amplitude inversion of S-wave accurately and thereby, eventually to generate lamda-rho, mu-rho volume for the whole of Mumbai High Field to characterize the carbonate reservoirs confidently; although the definition of the 'Carbonate Line' is likely to improve with the availability of more number of Shear wave logs.

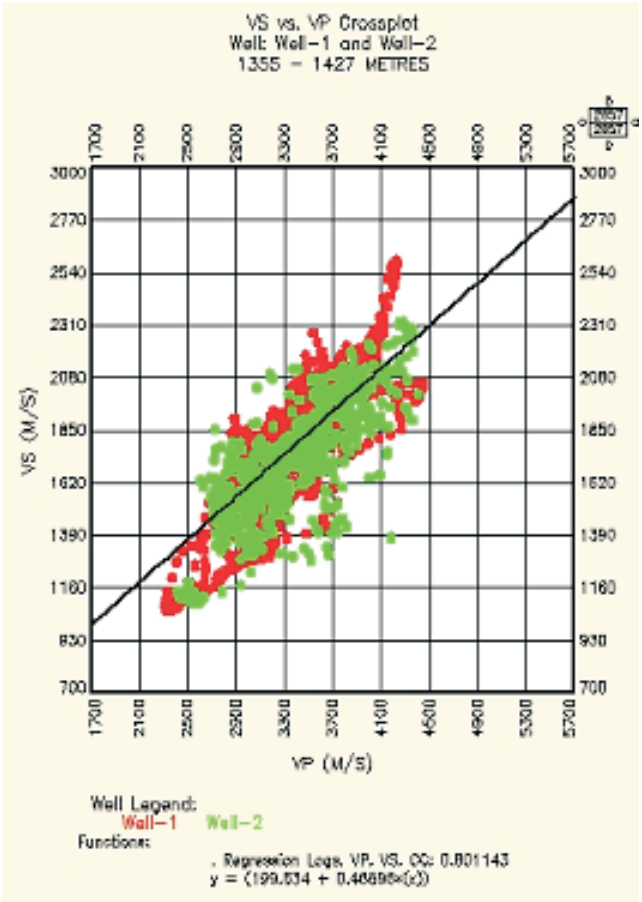

Fig.5 : Cross-plot between Vp and Vs

Conclusions

The Mumbai High L-III reservoir is a highly heterogeneous multi-layered carbonate reservoir and it is imprtant to understand reservoir properties more accurately using seismic amplitude inversion. A suitable relationship between P-wave and S-wave velocties is required to convert existing P-wave log to S-wave log in Carbonate reservoir. By cross-plotting P-wave and S-wave velocities within the carbonate zone, a linear relationship can be derived with high correlation co-efficient which enables us to use the P-wave log for S-wave amplitude inversion accurately. With the availability of more number of Shear-wave logs, the definition of the 'Carbonate Line' will be better constrained.

References

Yongyi Li and Jonathan Downton (TLE, July 2003), 'Recent applications of AVO to carbonate reservoirs in the Western Canadian Sedimentary Basin', pp. 670-674

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