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Hydrocarbon exploration Panna Formation in South Mumbai High-DCS area

Abstract

Seismic interpretation and attribute analysis with well-defined geo-model is the key of integrated interpretation which is more fruitful now a day. In many cases the interpretation process is simply a systematic collection of seismic attributes without any direct relation to a particular geological model. This model will vary from area to area depends on local geology & stratigraphic correlation of the wells. We are discussing how the lithology impacting the seismic trace & the derived seismic attributes will bring out the most plausible geo-model. Sand isolith map in corroboration with seismic waveform can reveal geological episodes depicts hydrocarbon accumulation & entrapment. Seismic facies generated under various neural network procedures, to subdivide regional facies determined from logs into productive and non-productive subfacies, and the cross correlation of seismic waveforms to provide a reliable map of the various facies present in the area. The present study of D33 area covers south Mumbai high and DCS blocks where Panna formation is the main hydrocarbon bearing zone. This has been divided in to five units starting from bottom to top. The bottom three Unit-I, II, III are LST/TST packs, whereas the top two Unit-V & Unit-IV are TST/HST packs. Hydrocarbon accumulation is seen only in the top two units.

Key words: seismic facies, Panna Formation, Unit-V, Barrier bars, Coarsening upward, sandstone

Introduction

The hydrocarbon find within Panna formation had given fresh impetus to exploration in and around the southern pericline of the Bombay platform. In this field, out of seven wells drilled, three wells A, B, and E have given commercial oil & gas whereas the well D has given non-commercial gas from the coarsening upward sequence in the uppermost part of Panna Formation during initial testing. The area requires thorough understanding of the source-reservoir-entrapment relationship and also the reservoir geometry for identifying the prospective areas for further exploration and appraisal. Base map of the study area is given in figure 1.

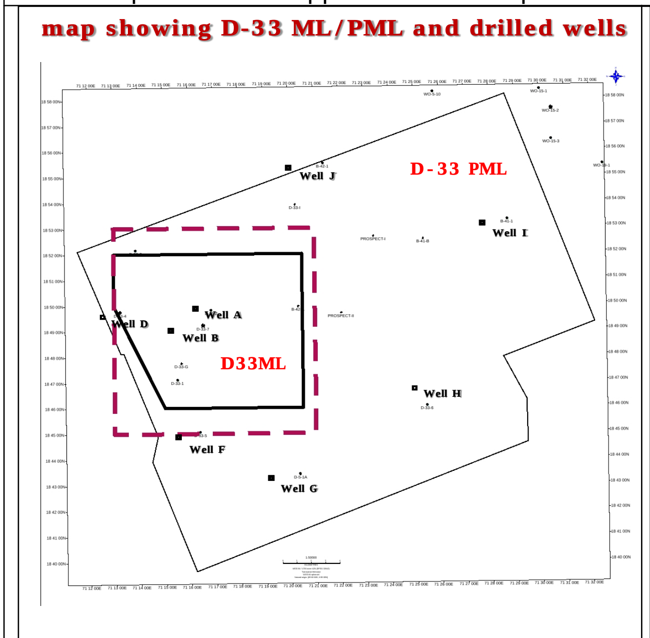


FIG. # 1

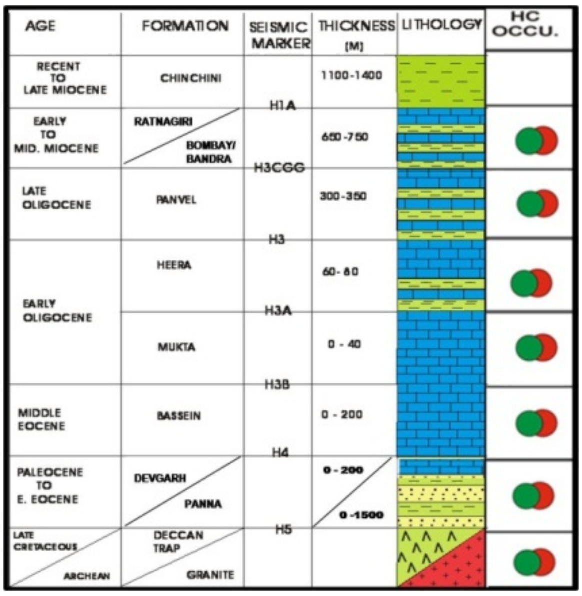
Tectonic setting

The Mumbai Offshore basin evolved as a pericratonic passive margin rift basin formed by the separation of Seychelles continent from the Indian Craton and located on the continental shelf off the Indian west coast (Biswas S.K., 1986) during Late Cretaceous period. The sedimentation in Mumbai Offshore Basin was initiated during the Late Paleocene period after the eruption of Deccan Basalt. Subsequent to the opening up of the basin initiation of the sedimentation took place in DCS area from NW, N & NE surrounding the main mumbai high platform. Structures of study area are separated from the main Mumbai High structure by a gentle southerly dipping homocline. Trans-tensional forces led to longitudinal split along NW-SE Dharwarian trend given rise to series of horst and graben features. The ENE-WSW faults (Satpura trend) compensate the extensional trend by off-setting it. The fault pattern is primarily guided by three major older trends i.e. Aravalli trend (NE-SW), Satpura (ENE-WSW) and Dharwar (NNW-SSE). Three phases of basin development have been recognised in Mumbai offshore Basin.

First marine transgression was witnessed during early part of Paleocene. Subsequently, extensive transgression during late Paleocene and Early Eocene has deposited clastics in the proximal part where as carbonates were deposited in the distal part further south of the study area within basin. The area had experienced the first tectonic pulse probably by the close of Paleocene/Early Eocene which resulted in the uplift of a large part of the southern DCS area and recorded a minor hiatus.

It is envisaged that this tectonic pulse has manifested into a number of discreet highs. The onlapping sequence grades from silt, coal, shale to sand followed by carbonates. Therefore the whole system from barrier complex, swamp, tidal flat to carbonate bank is backstepping i.e. a progressive transgression was occurring.

GENERALISED STRATIGRAPHY



In the study area, the Deccan Trap Volcanic of late Cretaceous age constitutes the Basement rock. The Basement (top of Deccan Traps-H5) is overlain by Panna Formation (Panna top/Devgarh top marked as H4) of Palaeocene to early Eocene age. Panna sedimentation is marked by continental to transitional marine set-up. Initial rifting during early to late Palaeocene has created two distinct broad terrace features (Paleo shore-lines) in south Mumbai high area. First terrace feature is seen south of Mumbai High & north east of study area along west to east and the second terrace feature is observed in area considered for this study. Devgarh formation is overlain by carbonate of Bassein formation of middle Eocene age. During Bassein transgression flooded lower reaches further north east inlier with shallow marine set-up. Platform carbonate regime was established with narrow inter-tidal zone all around inlier except north. Middle and upper Bassein regime was marked by shallow marine open sea environment with well-established platform carbonate set-up.

Early Oligocene Mukta formation transgression resulted in flooding of exposed shoal areas once again under shallow marine conditions. Early Oligocene (LVI) transgression submerged complete structure along with Mumbai High for the first time under shallow marine set-up. Higher reaches of the inlier formed shoal areas.

Exploration history & established hydrocarbon plays

Initially hydrocarbon exploration was targeted to delineate wedge-out prospects of Panna, Bassein and Mukta Formations, which has given lead to the discovery of WO-5 field (1992) and WO-15 field (1995). Later exploration was targeted in DCS area that led to the discovery of D-33 field in 2005. D-33 structure is a broad terrace feature situated in the south-western part of Mumbai high in DCS area.

The established hydrocarbon plays in the study area are as under :-

1) Sands within Devgarh Formation of Early Eocene age (Oil in B-41 Field)
2) Sands within Panna Formation of Palaeocene age (Oil in D-33 field)

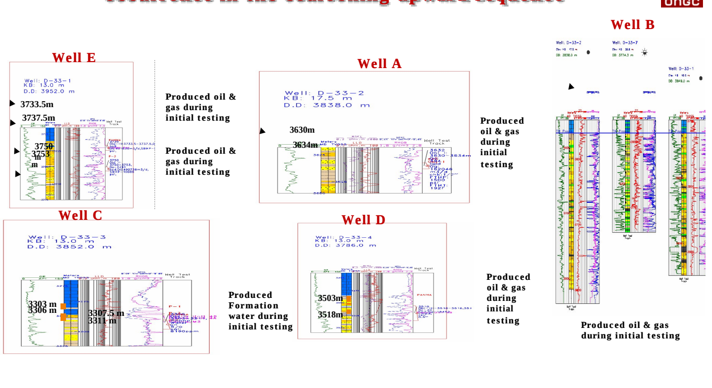
Exploration model

Rift related basin forming tectonics has created two broad terraces in the southern part of Mumbai high, first one is north of study area and the second one is in the south. The first terrace (younger terrace) is observed to be the locale for the deposition of Panna and Devgarh sandstone reservoirs of Palaeocene to Early Eocene age and the development of Bassein carbonate reservoir of Middle Eocene age. The second terrace (old terrace) is observed to be the locale for only Panna sandstone reservoir. Three sets of faults are observed in the study area: (1) EW Basin forming faults, (2) NS to NNE-SSW basin modifying faults and (3) Post mid Miocene reverse faults (late formed structures). Out of these three sets, basin forming faults have created broad terraces and helped for accumulation of Panna and Devgarh clastics. NS to NNE-SSW basin modifying faults have helped in reversal of pre-existing basin forming faults and helped in fluid migration and entrapment of hydrocarbons.

Panna Formation

The Basement (top of Deccan Traps-H5) is overlain by Panna Formation (Panna top/ Devgarh top marked as H4) of Palaeocene to early Eocene age. Panna sedimentation is marked by continental to transitional marine set-up. Panna Formation is dominated by sandstone, siltstone, coal, shale and towards basin side limestone and silty shale are dominating. Coarsening upward cycles are observed in the topmost part of Panna Formation (Unit-V). Hydrocarbon accumulation was seen mainly in this unit and the reservoir sandstone is having 13-18% porosity. Below Unit-V is Unit-IV which is mainly siltstone-sandstone layers with medium to thick coal beds.

Fig.2 Log signatures of Panna Formation showing hydrocarbon occurrence in the coarsening upward sequence



Log characters indicate mixture of fining upward and coarsening upward cycles with increase in gamma ray. (Fig. # 2)

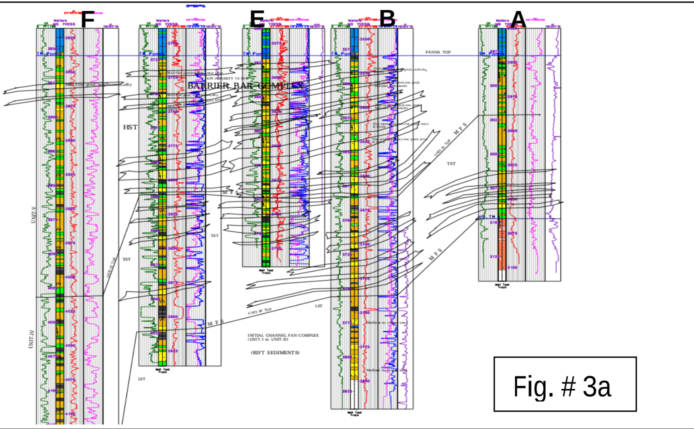


Fig. # 3a

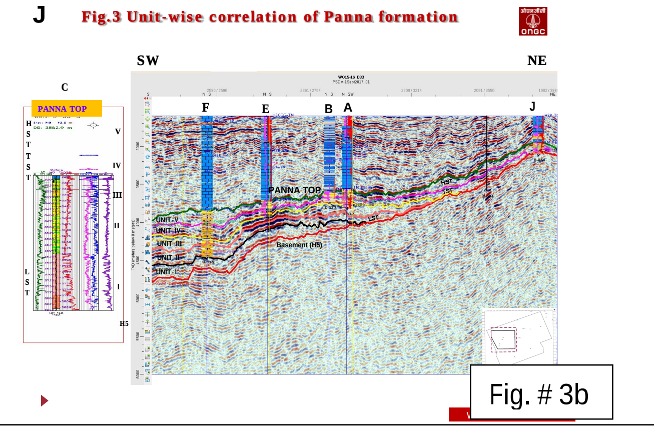


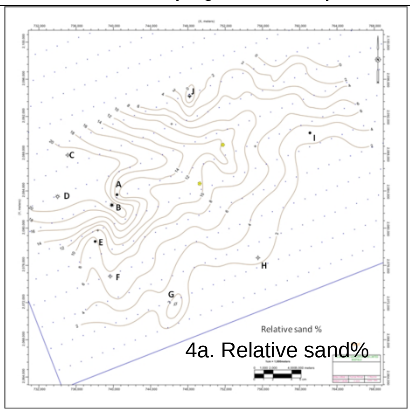
Fig. # 3b

Panna Formation is broadly divided in to five units starting from bottom to top Figure # 3a & b. The bottom unit-I, II, III are LST/TST packs, whereas thetop two units IV & V are TST/HST packs. During transgression the coastline moves landwards and the shelf area enlarges. This is accompanied by a tendency to have more sediment trapped in the alluvial and coastal plain environments. Transgression may be continuous or punctuated (HST), the later occurring by alternation of coastal retro gradation and regression despite a long term, landward stepping of the shore zone. This commonly results in Shore face retreat and drowning of in-place barrier.

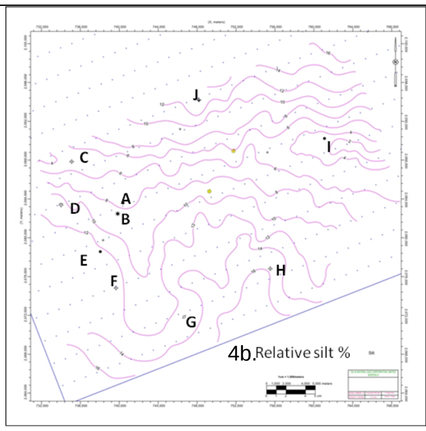
This phenomenon of shore face retreat and the development of Regressive barrier bars are seen in the study area as classic coarsening upward cycles of unit-V with an erosional unconformity. Stratigraphic correlation is given in Figure # 3b. Bottom-most unit (Unit-I) is interpreted as LST with the occurrence of trap-wash. This is followed by deposition of several transgressive - regressive cycles (Unit-II to Unit-V). Out of the five units, topmost unit (Unit-V) is hydrocarbon bearing.

In the complex geological set-up identifying the good locals of hydrocarbon accumulation and entrapment is not an easy task. well-log trend, seismic trace pattern can be used to define a depositional facies though the patterns of the synthetic traces created from sonic and density well logs do not perfectly match the real seismic traces because of different measurement scale, assumptions, and noise involved. However, they indicate that different depositional subfacies and reservoir distribution correspond to the changes in seismic trace patterns, which is the petrophysical basis for using seismic trace pattern to construct depositional subfacies. Structurization & the fault plains segmentation deforms seismic trace, in addition the enfluence of lithologic compostion involve significant changes in seismic trace pattern.

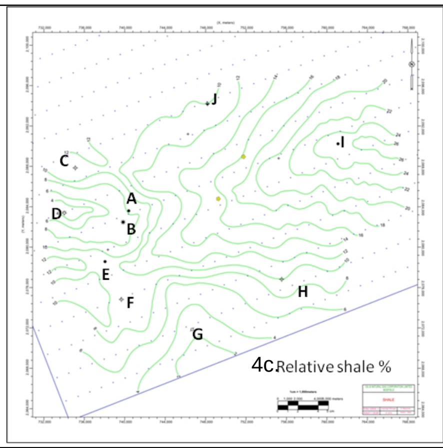
Interpretation of seismic facies data for pattern recognition helps directly to find out geological causes responsible for the seismic signature of a seismic facies unit. Seismic facies analysis is useful at predicting geological setting, type of stratification, geometry of the geological body corresponding to the seismic facies unit, its lithology, fluid content, porosity, relative age, overpressured shales. Indirectly some aspects of geological evolution (uplift, subsidence, erosion, transgression, regression), Depositional environment and processes, sediment transport direction can be interpreted. Integrationing the well lithology, log signatures & seismic facies we predicted the lithology from known places to unknown areas. We understand that all the lithologic units can not contribute to the seismic trace because of the seismic principles but layer impedance contrast between the lithogy units can enfluence the seismic trace and that can differentciate trace to trace varition which forms the distinct patterns. Lithology composition of 20mts thickness of Unit-V from pannatop formation having Sand, Silt, Shale, Lime, Coal units were corelated well to well & relative percentage maps guided by Time structure map were integreted with the seismic faceis (Figs 4a to 4f).



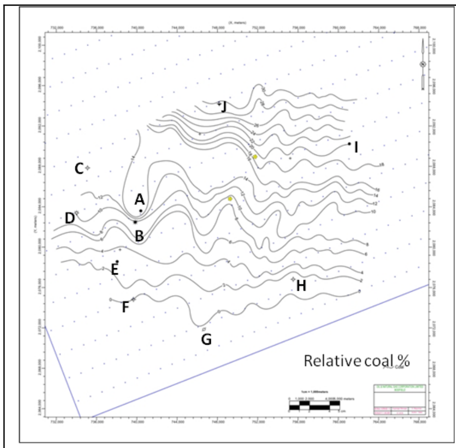
4a. Relative sand%

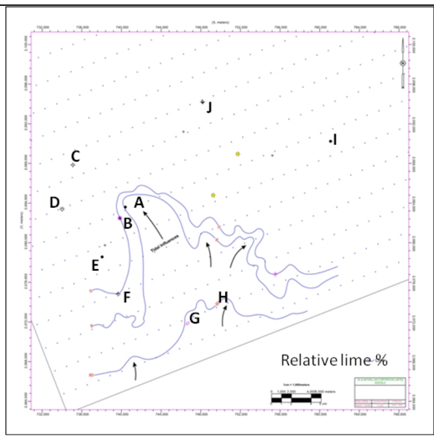


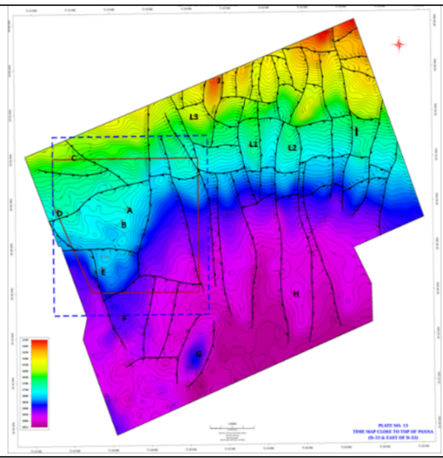
4b.Relative silt %



4c.Relative shale %







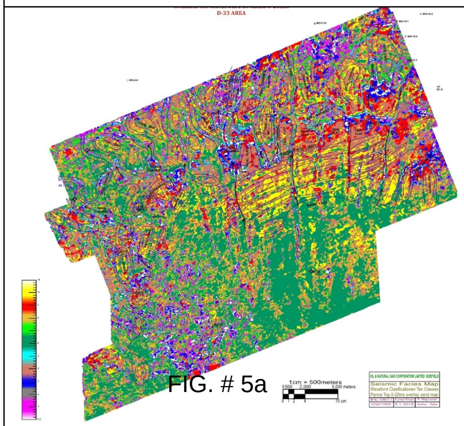


FIG. # 5a

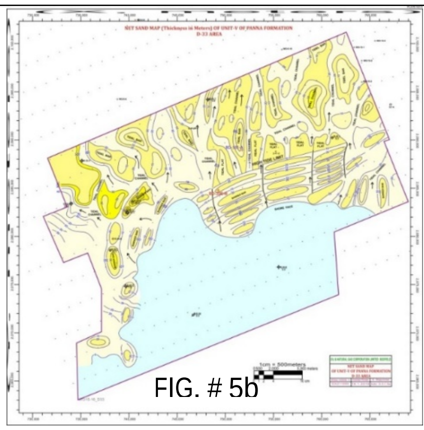


FIG. # 5b

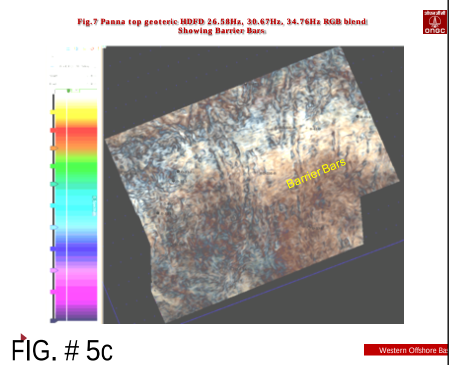


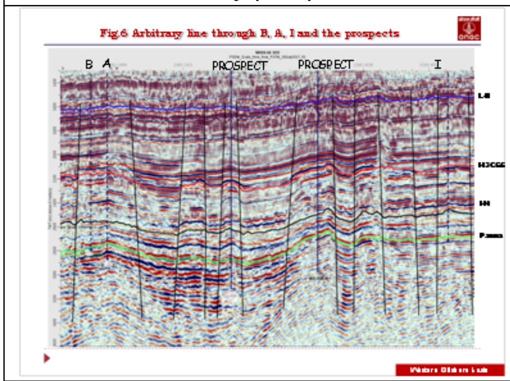
FIG. # 5c

Sand isolith map of unit-V (Figs.5a & b): Transgression may be continuous or punctuated (HST), the latter occurring by alternation of coastal retrogradation and regression despite a long term, landward stepping of the shore zone. This commonly results in shoreface retreat, barrier in place drowning. This phenomenon of shoreface retreat and the development of regressive barrier bars are interpreted from the sand isolith map of unit-V after matching with the seismic waveform trend. These regressive or drowned barriers are classic coarsening upward cycles of unit-V with erosional unconformity. High defination frequency decomposition RGB Blend of three frequency slices, 26.58Hz, 30.67Hz, and 34.76Hz carried out in Geoteric software (Fig. # 5c) also clearly high lights the barrier bar complex, channels, and other depositional features.

Seismic Attribute Studies

Waveform classification carried out to understand various lithofacies. Seismic reflection is impacted due to lithological layer thickness, velocity & density of sand, silt, clay/shale, coal, limestone, if these units having impedance contrast within seismic resolution. Waveform classes can be correlated to the depositional sub-facies. Waveform classification (Ten Classes) within 0 to 20ms windows below Panna top taken to identify the lithofacies of Unit-V (topmost unit) of Panna Formation. Waveform patterns depict barrier bars, tidal channels, tidal bars and shore face bars. This attribute was used to prepare sand depositional model with the help of net sand encountered in the drilled wells (Fig.5). Waveform between 60 and 120ms below Panna surface was attempted to bring out the lithofacies equivalent to Unit-IV of Panna Formation. This attribute was used to prepare sand depositional model with the help of net sand encountered in the drilled wells. (Fig. 6). Integration of other seismic attributes were also studied but not incorporated in this paper. High Definition frequency decomposition has been carried out in Geoteric. On Panna surface RGB Blend of three frequency slices, 26.58Hz, 30.67Hz, 34.76Hz highlights the area of barrier bar complex/channel pattern and depositional features (Fig.5c).

Based on the study prospects identified were shown in an arbitrary seismic line and given in the figure below.



Conclusion

Sand geometry deduced from seismic attribute analysis and well to well correlation has delineated regressive barrier bars (coarsening upward cycles) of uppermost unit (Unit-V) of Panna Formation. These regressive barrier bars are well developed towards east of D-33 field and are the potential targets for hydrocarbon exploration & delineation.

Acknowledgement

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