

Micro Depositional Environment and Reservoir Delineation through Integrated Log Interpretation in the Fields of Tapti-Daman Area, Western offshore Basin, India

V. L. N. Avadhani*, Pothana Prasad, Subhash Kushwaha, B S Haldia, R Solomon, P. P. Deo
CEWELL ONGC, Vadodara
Vln_avadhani@ongc.co.in

Keywords

Depositional environment, Ternary plots, litho-facies

Summary

An innovative integrated approach, using high resolution image logs, litho-facies analysis, and macro-depositional components from conventional log/geological correlations is developed to delineate reservoir orientation and understand the fluid distributions within sandstone reservoirs of Daman Formations of B-12, C-26 and C-24 Fields of Tapati-Daman Block of Western offshore Basin, India. The mega features of the depositional environment, transgressive, regressive cycles along with MRS are deduced with more sensitive Resistivity-Sonic Overlay while the stacked channel/bar nature of the deposits in prograding delta is brought out by high resolution image analysis along with conventional logs. Facies analysis carried out fairly corroborates with core and image observations. Extensive cross plotting of K, Th, U concentrations, NMR porosities geochemical log ternary plots, micro sedimentary features from image logs and core studies are amalgamated to characterize the sands which are manifested as high amplitude geo bodies from Seismic perspective, The wide spread sand units developed towards the bottom of regressive phase are having single fluid distribution system in B-12 and C-24 structures while upper sand units developed in transgressive phase are having hydrocarbon occurrences of stratigraphic nature.

Introduction

The study area (Fig 1) of this province consists of the Cambay Graben created during late Cretaceous failed rifting and a delta extending southwest from the graben toward the Bombay shelf. Dahanu and Surat Depression of the Tapti-block were remained main depositories of clastics during the Tertiary period (Wandrey,2004, Shukla,2011). The deposition of Daman formation is varying between delta plain to inner shelf environment and showing prograding

deltaic/point bars in near coastal deltaic regime, under regressive sea level conditions. The sandstone bodies deposited under tidal, wave or fluvial regime form the reservoir rocks in the area. The structural, stratigraphic as well as strati-structural entrapment conditions are observed in this area are restricted to the Daman and Mahuva formations of Oligocene age. Lithologically the Late Oligocene sequence is represented by alternations of sandstones, siltstone and shales along with streaks of carbonaceous matter in B-12 area (Fig 1). Few limestone streaks are observed towards the bottom part of the sequence. Conventional core data suggests that the sands are medium to fine grained, moderately sorted, calcareous. Sedimentary structures including cross laminations, flaser beddings, load structures, burrows and cut and fill structures are observed. The objective of the present study is to workout detailed depositional model for Daman sands by integrating all conventional, advanced log data along with core studies for reservoir characterization and sand orientation.

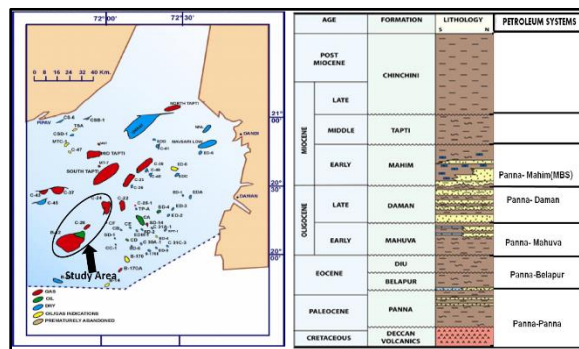


Fig1. Study Area and Generalized Stratigraphy

Study Approach

A generalized work flow of the study approach is given in Fig 2. Basic logs viz, Gamma Ray (GR),

Micro Depositional Environment and Reservoir Delineation through Integrated Log Interpretation in the Fields of Tapti-Daman Area, Western offshore Basin, India

Neutron Log (NPHI), Density Log (RHOB) and Sonic logs (DT) are used to generate lithofacies. Multi-Resolution Graph-based Clustering (MRGC)

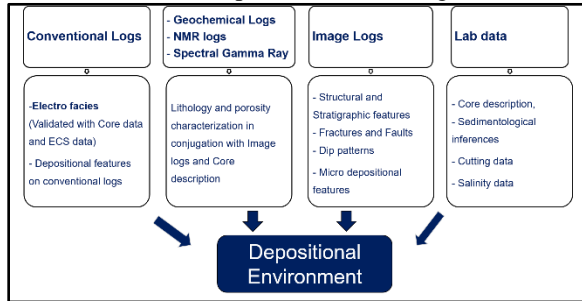


Fig 2 Study Approach

technique (Ye & Rabiller 2000) is used for lithofacies generation, the results are validated with geochemical logs and available cuttings data. Cross plots of spectral gamma ray logs (NGS), elemental capture spectroscopy logs (ECS), Nuclear magnetic resonance logs (NMR) and basic logs are generated formation wise and sand unit wise. Image log processing is carried out following the steps include data QC, speed correction, image equalization, bad button correction, static and dynamic normalization and eccentricity correction. Dips are picked on processed image log. Interpretation of processed image log is done correlating with modeled lithofacies, sedimentological studies and core descriptions. Salinity data from testing, MDT and logs are compiled.

Different log data responses are analyzed together with cutting and core data to find the suitable logs to understand the gradational sequences. In the study area shales are characterized by lower resistivity (RT) and longer transit time (DT) compared to that of sands, including water bearing sands. Hence the overlaid RT-DT on a compatible scale give at good indications of gradational sequences. Response of RT (True formation resistivity) and DT show a good representation of gradational sequence. Further, the variations in gradational sequences are correlated regionally and then interpreted in terms of major transgressive and regressional sea level fluctuations and their proximal boundaries (Fig 3). The maximum regression phase is identified with lesser separation on the overlay while MRS (Maximum Regressive Surface) culminates with both RT-DT completely overlaid on each other. The transgressive

environment is identifiable with maximum separation on RT-DT logs (Fig 3).

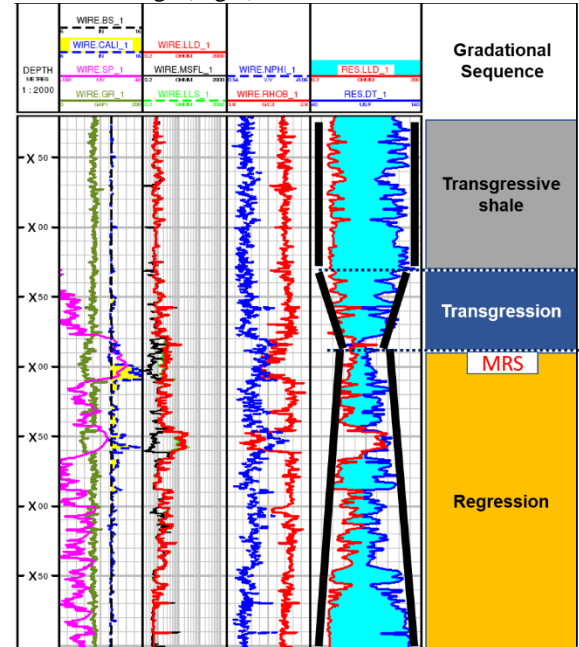


Fig 3. RT-DT overlay identifying depositional environment components

Discussions

In general, the Daman sands are developed in the interval 2000-2600m in the study area. The sand being developed at the bottom of the stratigraphic unit is named as Sand-6 while the sand-1 is the shallowest one. The available set of geological, sedimentological, paleontological data deduced from the core and cutting samples was integrated with mainly resistivity image data along with cross plot analysis of both conventional and advanced log data and facies analysis.

The depositional characteristics of individual sands are identified from the above integrated analysis and are further corroborated with the available seismic attribute maps.

Resistivity image data available in the wells is made use of to understand the sedimentary structures, internal organization of beddings and defining the micro depositional features along with the reservoir orientations. Due to low Basinal slope the structural

Micro Depositional Environment and Reservoir Delineation through Integrated Log Interpretation in the Fields of Tapti-Daman Area, Western offshore Basin, India

dip is very low and even the sedimentary dip patterns are not uniquely definable. However, the lithofacies analysis coupled with image characteristics define the depositional processes. The depositional components of deltaic and shallow marine environments viz. cross bedding, tidal effects, and pyrite presence could be inferred from the image logs

Image log characteristics

Image logs in sands dominantly characterized by highly cross bedded dips and massive type deposition (Figure-4). The cross-bedded dips indicate that the study area probably continuously reworked by marine processes during the deposition (Figure 14). It is also observed that the dips are bioturbated. The sand is disturbed by bioturbation during and post deposition. The paleocurrent directions observed from the blue patterns in the dips are changing with location in the basin. In general, the paleocurrent direction is dominantly towards west and southwest.

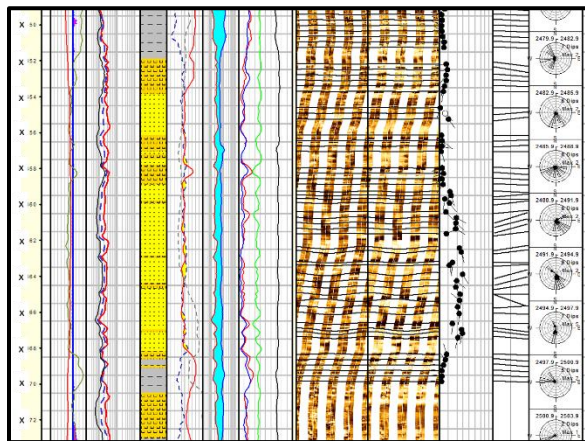


Fig4: Resistivity image log identifying cross bed nature, influence of Marine Processes .

Shale sections are characterized by thin laminations with very low structural dips (less than 5 degrees) and massive structureless claystone (Figure 5). The gently dipping shale lamina probably indicates a low basin topography and slow sedimentation in shallow marine settings. The structureless claystone depositions probably represents splays, tidal flats and inter distributary areas.

Most of the intervals in Daman formation is bioturbated to various degrees (Figure 6), suggesting favorable environmental conditions to the development of a burrowing in fauna. Occasionally calcareous precipitations are observed in image log as high resistivity and high density, indicating a hot and humid conditions. Carbonaceous matter and pyritic material presence in the image logs corroborate with the core data, which suggests a swampy condition in deltaic settings.

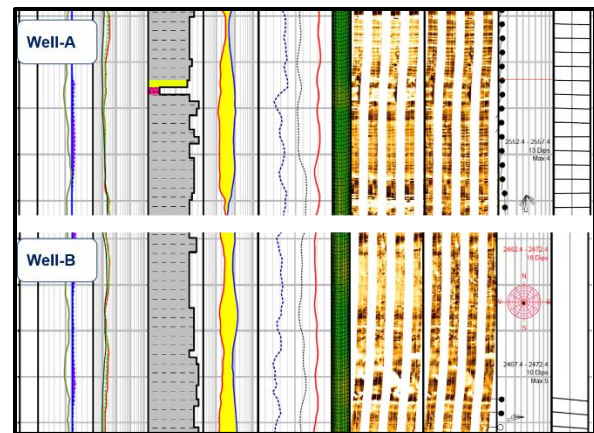


Fig 5: Presence of laminations and massive nature of the sands inferred from Image logs.

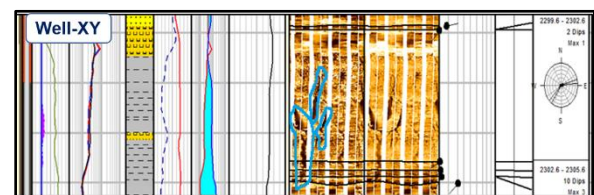


Fig 6: Bioturbation: Alongated burrowed features, filled by conductive material can be seen in image log (Highlighted with blue color).

Inferences from Geochemical logs and Nuclear magnetic resonance logs

The extensively available Spectral Gamma ray data was analyzed. Thorium and Uranium ratios in the study area suggest a shallow marine to transitional environment (Klaja and Dudek 2016). The increasing influence of marine processes is noticed in the wells located in SW part of the study area (Figure 7). Other spectral gamma ray log ratios show similar

Micro Depositional Environment and Reservoir Delineation through Integrated Log Interpretation in the Fields of Tapti-Daman Area, Western offshore Basin, India

results and also indicate the presence of Chlorite mineral and increase of Kaolinite towards SW.

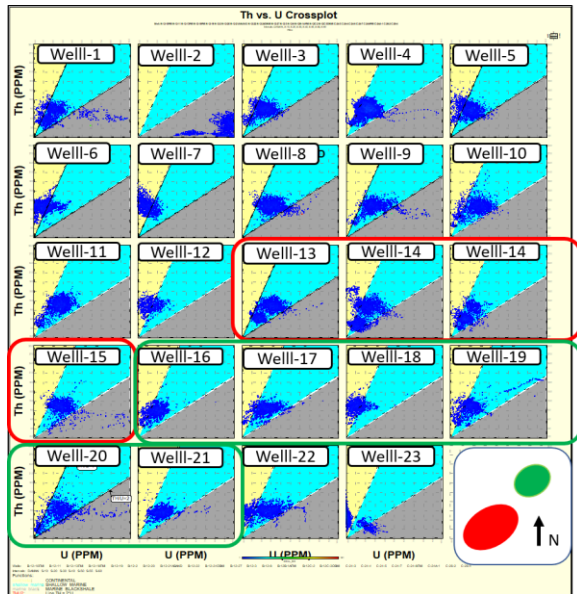


Fig 7: Th vs U plot indicates shallow marine to transitional settings. Towards SW there is subtle increase of marine influence. Wells from 13 to 15 are located towards SW (Basin wards) marked in red color and Wells 16 to 21 are located towards NE, marked in green color.

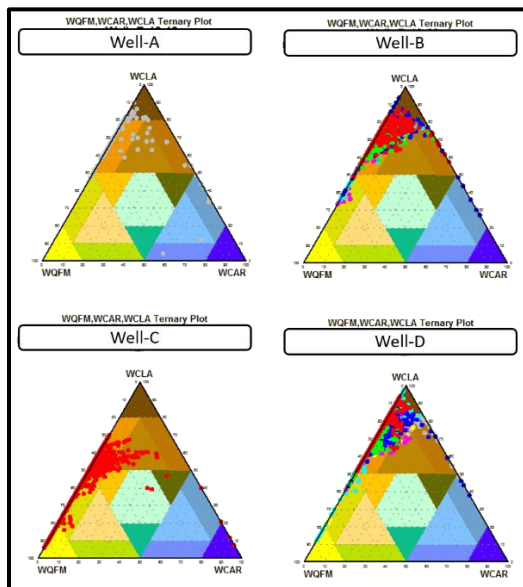


Fig 7: Ternary plots indicating Sands with clay and feldspars with minimum calcite presence.

The available elemental concentration logs also analyzed with the help of ternary plots. The inferences from these plots are that the Daman formation is clay rich clastic dominated and calcite depositions are not noticed (Figure-8).

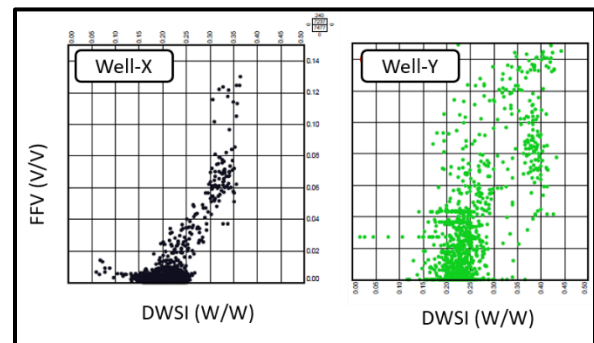


Fig 9: Cross plots of CMR derived Free Fluid Volume (FFV) versus Elemental concentration of Silicon (DWSI). Sands are characterized with High Free Fluid porosity.

Available Free fluid porosity from NMR logs of few wells also depict direct correlativity between Silicon content and free fluid porosity (Figure 9) thus ruling out presence of mafic high density minerals in the depositional environment. The low pyrite present in few layers as depicted by Image logs is in the form of nodules which does not affect the reservoir productivity.

Depositional Characteristics of Sand units

Analysis of DT-RT overlies together with sedimentological studies suggests that the lower Daman formation is mainly deposited in prograding deltaic environment associated with sea level regression and the upper Daman formation was deposited in transgressive marine settings. The dominant sand depositional nature is changing from ditributary mouthbars to distributary channels, from the bottom to top of Daman formation.

Facies analysis coupled with log characteristics define the gradational changes in the reservoir quality. A fluid contact identified in one well (Figure-10) could be correlated across the wells and

Micro Depositional Environment and Reservoir Delineation through Integrated Log Interpretation in the Fields of Tapti-Daman Area, Western offshore Basin, India

hydrocarbon occurrences in the stacked sand units deposited towards bottom of the regressive phase could be explained as their areal extents are better.

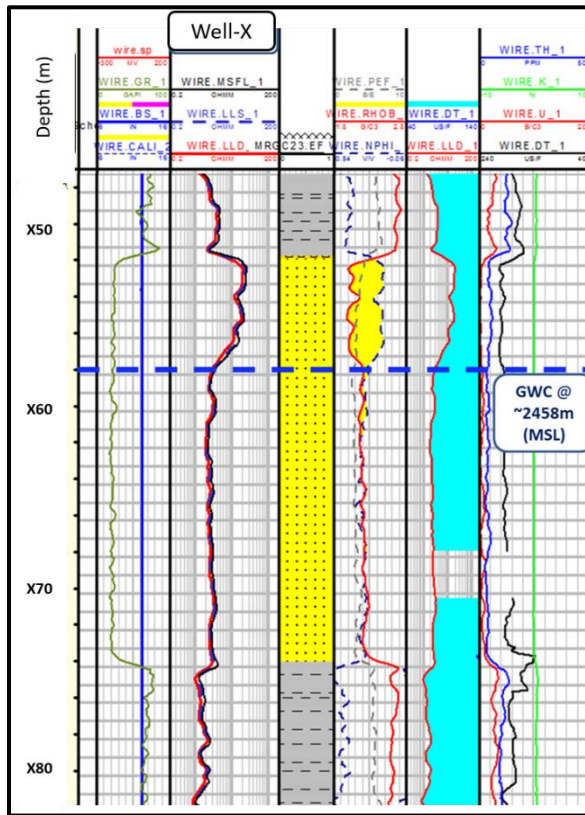


Fig 10. GWC identified in well could explain hydrocarbon occurrences in the bottom set of sand units.

The development of the sand units and reservoir characteristics show significant variations in the studied wells. The variations depend on the well location related to the provenance of the distributary channel systems (Figure 11). Cleaner reservoirs of good thickness are developed in the channel axis, while silty reservoir facies are developed in distributary mouth bars, crevasse splays, and levee type depositions. The wells, where no sand facies or silty facies are developed are characterized by shale which deposited as tidal flats, in marshy conditions and intense bioturbation is also observed. Facies analysis in this sand unit in the regressive phase also suggests the same.

The salinity data with a wider range both laterally and vertically in both regressive and transgressive phases indicates continuous periodical marine incursions.

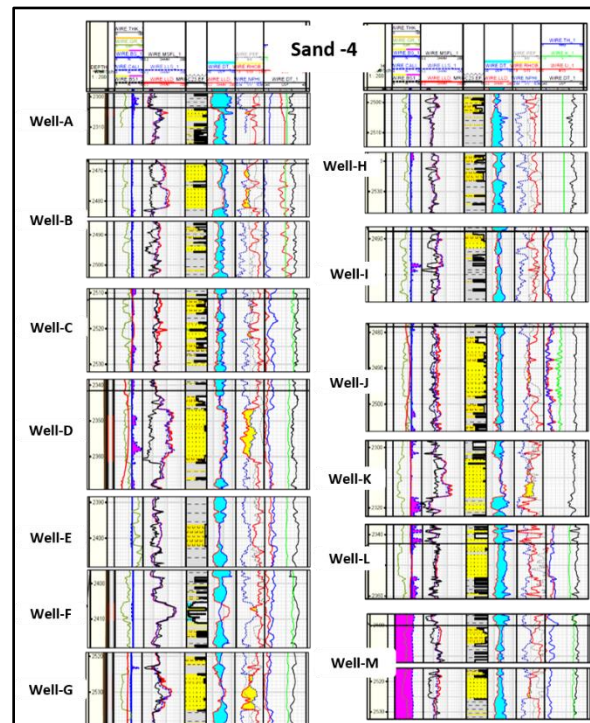


Fig 11: Reservoir characteristics showing variations from massive to silty as reflected in facies analysis.

The sand units within the upper Daman formation are deposited during the transgressive cycle, which are studied using facies analysis. Mainly the sands are identified as distributary channel depositions. These clean channel deposits are embedded in thick transgressive shale and probably isolated in nature (Figure 12).

The sand characteristics across the three structures indicate better sand development in the wells located in the distal area compared to proximal area. The other sand developed in the regressive phase has also

Micro Depositional Environment and Reservoir Delineation through Integrated Log Interpretation in the Fields of Tapti-Daman Area, Western offshore Basin, India

got better uniformity in reservoir characteristics and is widespread in the area.

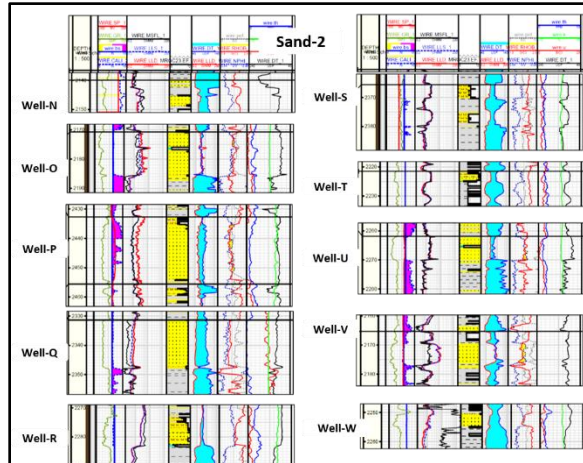


Fig 12. The subdued reservoir characteristics of transgressive sands with lesser areal extent.

The comparison of sand characteristics deposited in regressive and transgressive cycles are of good correlativity within the proximal Fields viz. B-12 and C-26. The Field located in the NE part of the study area viz. C-24 has got fewer sand units as expected with more gradational changes in short lateral span.

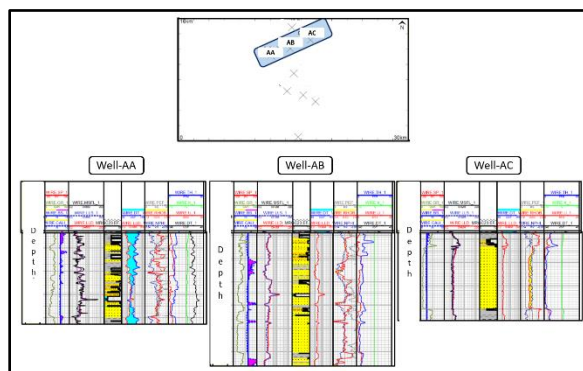


Fig 13. Grain size variations in three wells from NE-SW

This gradual variation suggests that this paleo channel flowing in a very low gradient topography with decreasing energy towards SW (Figure 13). The coarse-grained cleaner reservoir facies are developed in the NE part while fine grained sediments were deposited in the SW part.

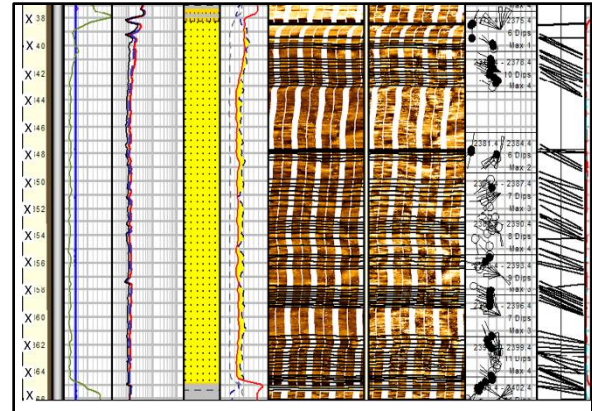


Fig 14. Image showing cross beddings with high dip angles.

Conclusions:

1. Daman formation comprises of three distinct sedimentological units deposited under the conditions of regression, transgression and mass flooding. Lower part of the Daman formation represents a major regression cycle. Upper part of the Daman formation represents frequent sea level fluctuations in transgressed environment followed by mass flooding.
2. The generated Electro facies have a good corroboration with lithological descriptions from core and cutting data. Resistivity-Sonic overlay helped in identifying regressive and transgressive cycles and helped in deducing the depositional environment.
3. The image characteristics coupled with facies analysis and log characteristics indicate that the sands developed in Daman formation have the characteristics of distributary channels, distributary mouth bars, crevasse splays and flood plain depositions.
4. Dips of image logs suggests that the paleo channel direction could be predominantly towards SW to W. The varying paleo flow direction of different distributary channels might be the result of low gradient basin topography and regional geological structures.
5. The shales were interpreted as deposited in tidal flats and inter distributary areas. The depositional area experienced frequent sub areal



Micro Depositional Environment and Reservoir Delineation through Integrated Log Interpretation in the Fields of Tapti-Daman Area, Western offshore Basin, India

exposure under hot and humid conditions forming calcite precipitations brought from tidal inlets.

6. The sand units developed towards the bottom of Daman Formation are inferred to have deposited in regressive phase while upper sand units are deposited in transgressive environment with minor regressive sea level fluctuations. These sands are having more lateral spread compared to other sand units having the progradational deltaic nature.
7. The integrated work flow developed bringing all the data could bring out the micro-depositional features and fluid distributions within the sands developed in regressive phase.

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