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Isolated Carbonate Buildups in Lower Oligocene Mahuva Formation, Tapti Daman Block : A potential New Play Type in the Western Offshore Basin, India.

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Summary

Present study has identified a previously unknown carbonate buildup within the Mahuva Formation in the Tapti Daman Block, Western Offshore Basin of India. Thin carbonate beds within shales are found to be hydrocarbon bearing in this area, which has produced small volumes of oil and gas in the Dahanu and adjacent structures. The carbonate buildups can represent a significant new play type in the Tapti Daman sub Basin, where shales and limestones are known source rock. The present carbonate buildup, imaged as a lens like event in three-dimensional seismic data, forms an elliptical feature in the isopach, amplitude, impedance and velocity maps. It is characterized by generally high but variable seismic amplitude, and its thicknesses (30 to 40 m) exhibit a complex pattern, suggesting weathering and/or localized carbonate growth. A relationship between impedance and porosity was derived. Using this relationship the seismically derived impedance values were converted to porosities. The derived porosities, perhaps, qualitatively demarcate the areas of better porosity developments within the build up. The lateral and vertical seals for this limestone reservoir are likely to be provided by the shales of Mahuva Formation. Considering the nature of anomaly, paleostructural disposition, thickness maps, seismic attribute studies, impedance/porosity analysis, fairly large size of the buildup, located within established Mahuva play, appears to be interesting from hydrocarbon point of view.

Introduction

Tapti-Daman Block in Western Offshore Basin of India is a Tertiary clastic sub-basin formed at junction of the Cambay and Narmada rifts and contains a sedimentary thickness in excess of 6000m. The present study is based on the evaluation of 3D seismic data falling towards south of South Tapti in the Tapti Daman Block of Western offshore Basin (**Fig-1**). The area spans over 350 km² with a total of 14000 LKM 3D data. It encompasses part of Dahanu low and south Tapti structure, where more than 200 m of Mahuva sediments were deposited during Early Oligocene time. Mahuva Formation forms an independent petroleum system as shales and limestones within Mahuva Formation

are established source rock in the basin and widespread occurrence of thick shales within Mahuva, are excellent vertical and lateral seals. In this part of the basin thin limestones within Mahuva are known producers in nearby Dahanu and adjacent structures but large commercial structures are not yet established within Mahuva Formation. The present study has identified a large isolated carbonate build up which is a different hydrocarbon play in this part of the basin.



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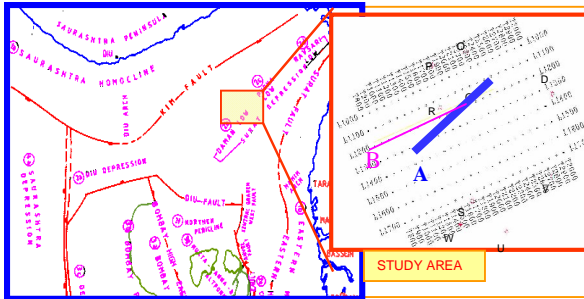


Fig-1: Location map of the study area

Tectonic And Geologic Setting

Tapti-Daman Block covers an area of about 27,000 sq. km. in the northeastern part of Western offshore Basin. It is bounded by Deccan trap outcrops in the east and north, Diu fault in the south and Diu arch in the west. It comprises Saurashtra Homocline, Eastern Homocline and number of ENE-WSW trending lows viz. Daman low, Purna low and Navsari low (Fig-1). More than 6000m thick Tertiary sediments have been deposited in the deepest part of the sub-basin. Sediments deposited in the area are predominantly under strong influence of clastic regime and represented by thick sequences of shale/claystone, sandstone, siltstone and occasionally carbonate and coal/carbonaceous matter. Proto Narmada and proto Tapti river systems are believed to be the major agencies for clastic supply to the basin. The major sediment influx is from NE and a minor contribution may be from the weathered trap materials bordering the margin to the east & north.

Stratigraphic Framework

The Tapti –Daman Block consists of Tertiary clastics from Palaeocene to Recent. The depositional lows contain thick sedimentary column. The generalized stratigraphic succession is shown in Fig-2. This paper is focused mainly on Lower Oligocene Mahuva Formation which unconformably overlies the Diu Formation. Mahuva Formation is subdivided into two units; the lower unit is represented mainly by thick, monotonous shale with occasional development of limestone. The upper unit is represented by thick shale with interbedded sandstone, siltstone and limestones. The Mahuva Formation is unconformably overlain by Daman Formation of Upper Oligocene age (Zutshi et al,1993).

AGE	FORMATION	EXPECTED LITH	H/C	DESCRIPTION	ENVIRONMENT OF DEPOSITION
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MID. MIOCENE TO RECENT	TAPTI & CHINCHINI			Clay stone, Shale with thin streaks of siltstone.	Tidal Shallow Marine
LOWER MIOCENE	MAHIM			Mainly Shale with thin streaks of siltstone	Tidal- Deltaic
UPP. OLIGOCENE	DAMAN		★	Shale, Siltstone and sandstone	Tidal- Deltaic
LR. OLIGOCENE	MAHUV A	Lower	★	Mainly Shale with siltstone, sandstone & limestone streaks	Shallow Marine
		Upper		Mainly Shale with limestone streaks	Shallow Marine
MID-UPPER EOCENE	DIU		★	Mainly Shale with limestone streaks	Shallow Marine
	BELAPUR				
PALEOCENE TO LOWER EOCENE	PANNA		★	Mainly Shale with sandstone streaks	Shallow to inner n
CRETACEOUS	TRAP/BASALMENT			Deccan traps	

Fig-2: Generalized Stratigraphy of Tapti Daman Sub-Basin.

Data Interpretation And Analysis

Data used in this study comprised of (1) 3-D seismic volume of around 350 Km² consisting of 14000 LKM with a bin size 25X12.5 m and (2) wire-line logs and stratigraphic tops from 25 wells. Well data include nine stratigraphic tops, time-depth tables, and various wire-line logs (spontaneous potential, gamma ray, resistivity, acoustic, neutron porosity, and density).

Horizon correlation and mapping

The seismic reflections within the entire stratigraphic sequence in the area are characterized by moderate to high amplitude and good continuity. The individual log signatures can also be easily correlated across the area. The structural framework was reconstructed for Mahuva Formation by correlating 7 horizons. Most fundamental and basic approach was adopted for understanding vertical lateral distribution of the stratigraphic units in the study area as given below.

- Understanding the regional tectonics and prevailing basement configuration vis-à-vis perceived paleodrainage systems during deposition of the sediments from published and unpublished literatures.



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- Mapping of tops as Basement, Lower Mahuva Top, Mahuva3, Mahuva2, Mahuva1, Mahuva Top, Daman Top (Fig- 3).
- Understanding the paleostructures from isochronopach maps of different units within it.
- Identification of reservoir facies within Mahuva from different seismic attributes as well as log facies analysis.

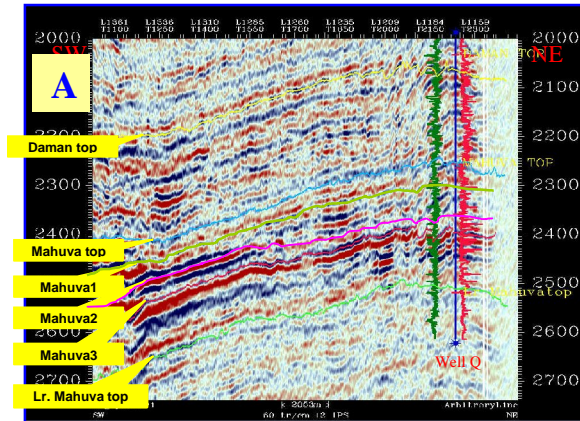


Fig-3: NE SW arbitrary line passing through the Well-Q showing correlated horizons and other features within Mahuva Formation. The location of profile is shown in Fig-1.

Fault identification and mapping

Time slices of coherency and basic data volumes, horizon slices of coherency and other attributes and illuminated voxel images of correlated horizons, dip and azimuth maps of horizons, volume, horizontal and vertical visualization of basic data were used for identification of faults. Time slice from coherency volumes at 2500 ms (Fig-4) shows fault trends and other discontinuities within Mahuva Formation.

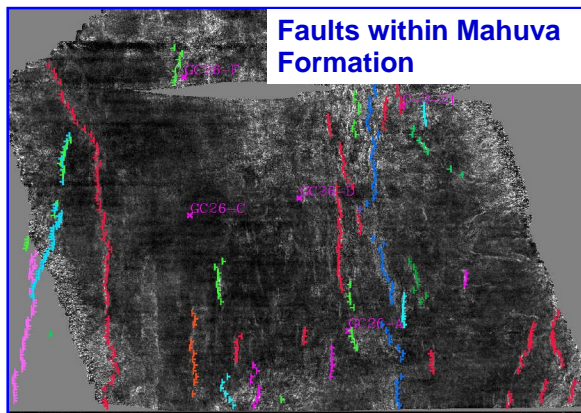


Fig-4: Coherency time slice at 2500 ms showing fault patterns within Mahuva Formation (intersection of faults shown)

Log facies mapping

Log correlation of about 25 wells from the study area (2 wells) and adjoining areas (23 wells) was done and detailed facies were mapped (Fig-5). Lower Mahuva unit and deeper sequences have predominantly shales and thin limestone streaks. In Upper Mahuva unit silty-sandstones/siltstones are also observed along with limestone streaks within predominantly shaly sequence. The limestone percentage increases towards southwest.

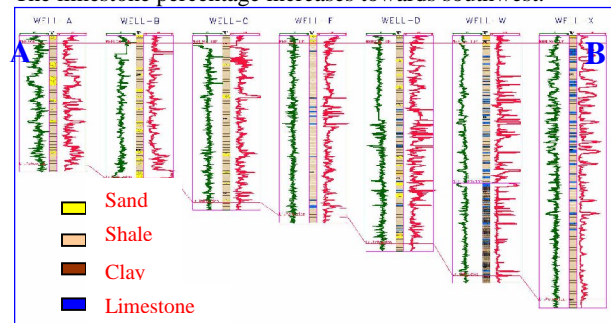


Fig-5: Electrolog correlation along well A, B, C, E, D, W and X. The profile is Flattened at Mahuva Top). The location of profile is shown in Fig-6.

Seismic Attributes Study

The mapped sedimentary column was analysed by extracting seismic attributes within sequences and within time windows with reference to mapped horizons, computing horizon slices of attributes and seismic trace data. 3-D visualization, seismic inversion, spectral decomposition and seismic facies classification were attempted to understand the spatial and temporal distribution of the facies within the identified intervals.

Identification of carbonate buildup

The study mainly focused on the identification of large drillable prospects within the Mahuva Formation. While analyzing the data a large amplitude anomaly within Upper Mahuva Unit between Mahuva2 and Mahuva3 reflectors was mapped. Considering the seismic characteristics and the regional lithofacies correlation, the anomaly was interpreted as a carbonate buildup. In the surrounding wells this stratigraphic interval is represented by shale with thin limestone intercalations. Overall limestone thickness (Fig-6) and carbonate percentage increase from NE to SW direction (Fig-7) which is in conformity with the

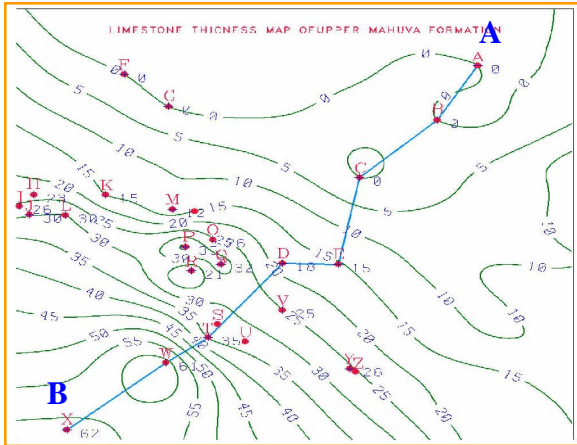


Fig-6: Regional distribution of carbonate facies within Mahuva unit Carbonate thickness increases towards SW. In well C it is zero.

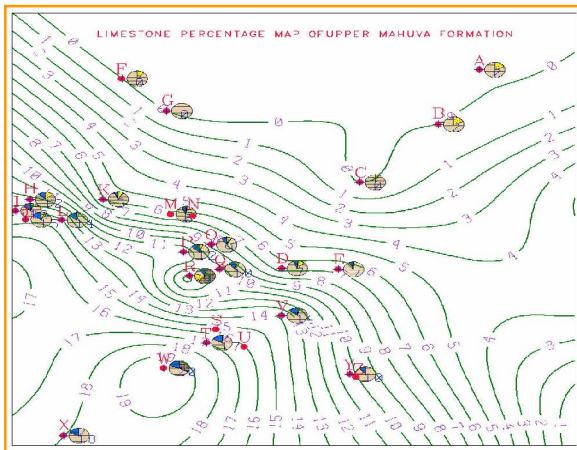


Fig-7: Regional pattern of carbonate to siliciclastic ratio within Mahuva unit Carbonate percentage increases towards SW. In well C it is zero.

envisaged clastic input from northeast. This inference is further supported by paleostructural analysis, seismic attributes, and impedance value and isopach maps. Structural relief and bright amplitude with reference to Mahuva2 (top of buildup) and high amplitude burst below Mahuva3 (bottom of buildup) are distinctly seen on the seismic sections. The structural relief is probably due to carbonate buildup over the Mahuva3 reflector. On the line 1200 (Fig-8) the buildup feature is distinctly seen.

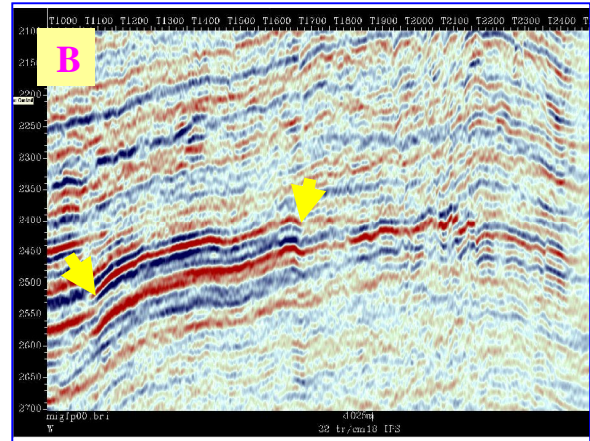


Fig-8: Line 1200 showing the carbonate buildup within Mahuva Formation. The location of profile is shown in Fig-1

The extension and attributes of possible carbonate facies around Mahuva2 are depicted from following displays:

1. Isochronopach between Mahuva3 and Mahuva2 shows thickening due to additional deposition of carbonates (Fig-9).
2. The paleostructural disposition of Lower Mahuva during the deposition of carbonate in Upper Mahuva Unit is shown in Fig-10. The paleo-relief could have favored the deposition of carbonate.
3. RMS amplitude within -10 to +10 ms window w.r.t. Mahuva2 (Fig-11) with overlay of time structure of Mahuva2 shows high amplitude in buildup area and sharp termination towards west against fault and gradual decrease towards east. The anomaly is distributed roughly in semi-elliptical shape with NW-SE major axis to the west of the area.
4. Horizon slice w.r.t. Mahuva2 (Fig-12) showing amplitude at top of buildup. The areal extension of the possible buildup is overlain on the anomaly map which is more than 50 km².
5. Impedance between Mahuva3 and Mahuva2 (Fig-13) showing that the relatively low impedance is surrounded by higher impedance.
6. Interval velocity within the anomalous area between build-up top and bottom varies between 2500 to 2800 m/s which is significantly higher than the background shale velocity ranging from 2200 to 2400 m/s. Relatively higher interval velocities may be caused by increase in limestone content within the interval

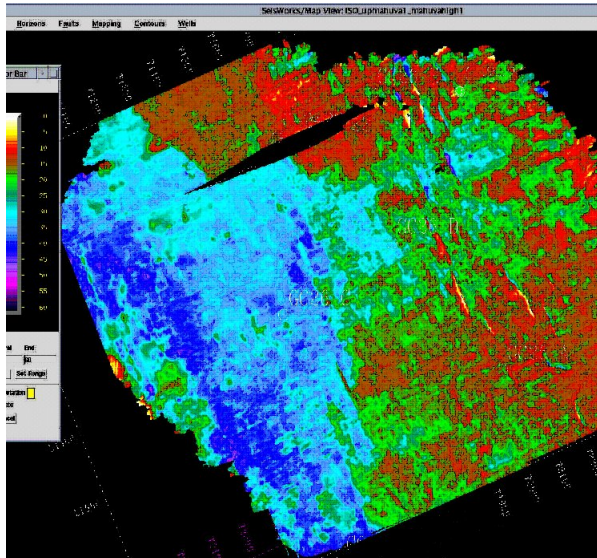


Fig-9: Isochronopach between mahuva2 (buildup top) and mahuva3 (buildup bottom) reflector

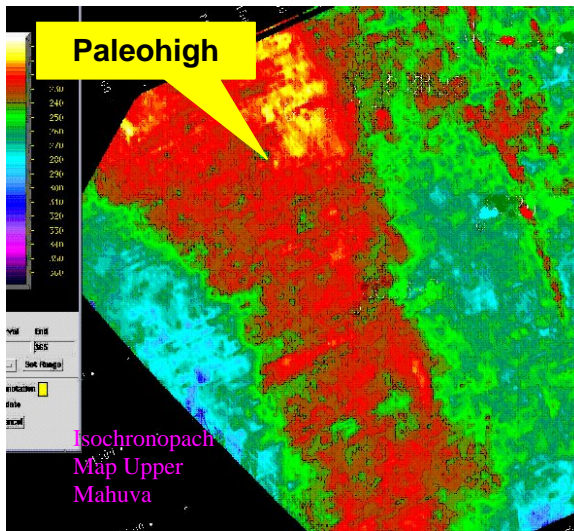


Fig-10: Paleostuctural disposition of Lower Mahuva during the deposition of carbonate in Upper Mahuva Unit

The log analysis of nearby wells shows that there are occasional developments of thin limestone streaks with thickness ranging from 1m to 5m. Using the log data the impedances were computed for various lithologies like limestones, shale, shaly-limestone etc. in the surrounding

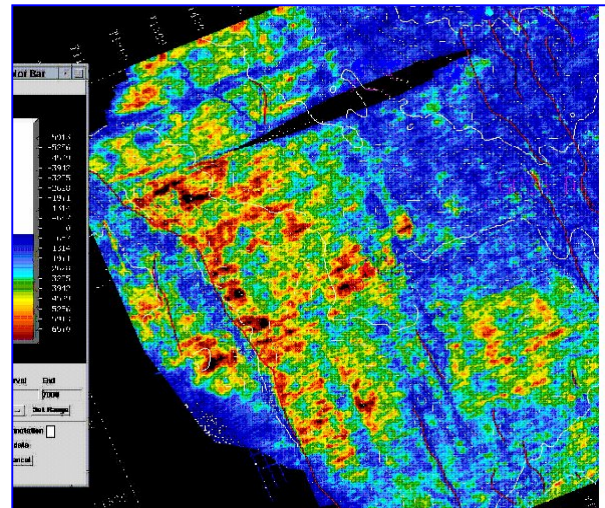


Fig-11: RMS amplitude within -10 to +10 ms window w.r.t. Mahuva2. The extent of carbonate buildup is marked by high amplitude.

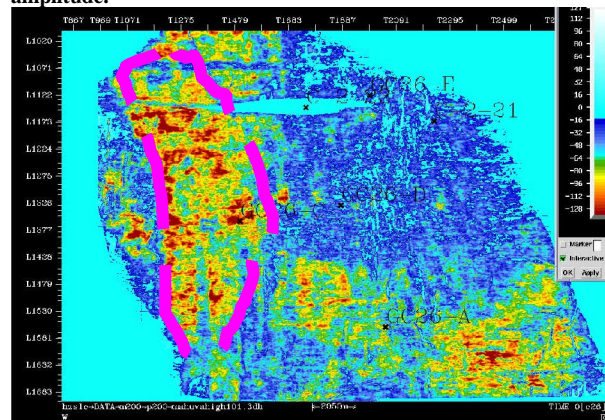


Fig-12: Horizon slice at mahuva2 (buildup top) showing extension of mapped carbonate body

wells. The acoustic impedance is able to discriminate the limestone, shale and shaly-limestone facies. These analysis shows that shales are having impedance ranging from 4000-8000 while limestone is having impedance in the range of 8000-14000 (Fig-14). Porosity vs. impedance cross plot (Fig-15) shows that impedance varies linearly with the porosity and low impedance correspond to high porosity within carbonates. A relationship between impedance and porosity was derived. Using this relationship the seismically derived impedance values were converted to porosities. The relative porosities within the anomalous zone vary from 3-11%. However, in view of fine lateral and vertical lithofacies variations, it may not be possible to have one to one correspondence between

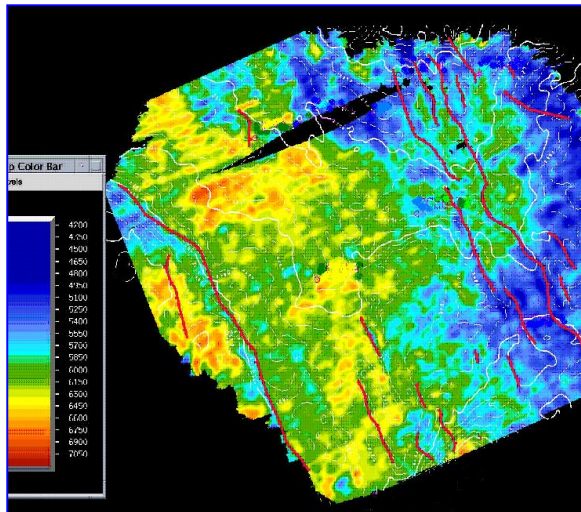


Fig-13: Impedance between Mahuva3 and Mahuva2 showing that the relatively low impedance is surrounded by higher impedance.

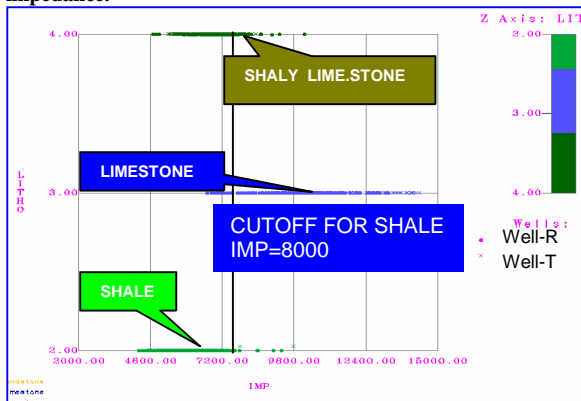


Fig-14: Lithology vs. Impedance Cross plot in Wells R & T where the impedance is able to discriminate limestone, shale and shaly-limestone facies

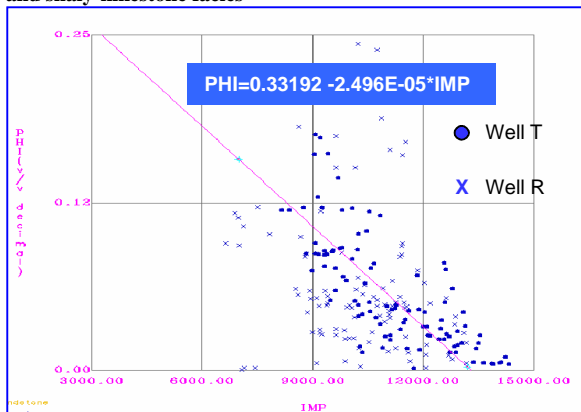


Fig-15: Porosity vs. Impedance Cross plot within Limestone in Wells T & R shows impedance varies linearly with porosity

impedance values and predicted porosities. The derived porosities, perhaps, qualitatively demarcate the areas of better porosity developments within the build up (Fig-16). The lateral and vertical seals for this limestone reservoir are likely to be provided by the shales of Mahuva Formation.

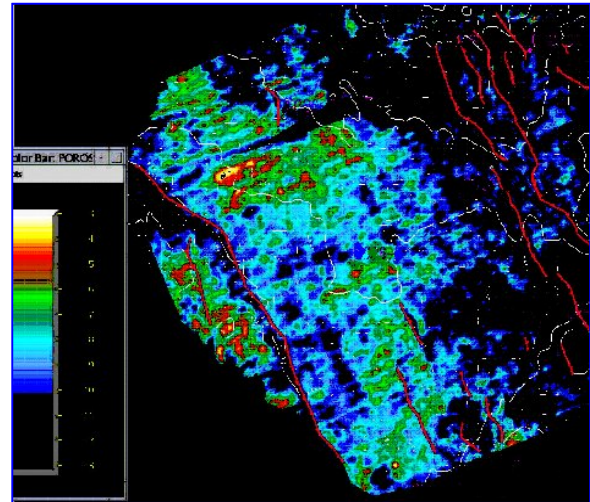


Fig-16: Porosity map showing the areas of better porosity developments within the build up

Source Rocks Potential And Maturity Modelling

Different workers carried out the source rock analysis of a number of wells in Tapti-Daman area. Those include mainly the geochemical studies, source rock palynological studies and maturity modeling. Based on the overall assessment of the source rock evaluation of the area, it can be concluded that sediments of Paleocene, Lower Eocene, Mid-,Late Eocene, Early Oligocene and Late Oligocene sediments are matured and having sufficient source rock character and generation potential (Balan et al 1989).

The Paleocene sediments form the oldest and thickest source rock unit (consisting mainly of type-III kerogen). The amount of TOC is also quite good in Surat depression (Between 0.5% to 3%). The Early Eocene sediments are quite thick in the northeastern part of the Surat depression with good TOC values (0.5%-4%).

Conclusions

Integrated evaluation of 3D data has identified an isolated, elliptical carbonate buildup within Mahuva Formation, where shales & limestones are known source rock. This has been further confirmed by isopach, amplitude, impedance and velocity maps prepared at the target level. This carbonate buildup can be a potential new play type and may



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contain significant amount of hydrocarbon opening a new opportunity in Tapti Daman Block where production has been marginal.

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