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Hydrocarbon prospectivity in Mumbai offshore, Western continental margin Area – A case study

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Abstract

The study area falls in Western offshore basin which extends from the present day shelf edge to the distal part of the present day continental slope with bathymetry range from 80m onwards. Many wells have been drilled in the area and all the wells are either dry except one well which is Gas bearing from Pliocene sandstone. As per In house laboratory studies the well has flowed biogenic gas from sediments of Contourite deposit at very shallow depth, which has open up a new concept of contourite deposit with accumulation of biogenic gas for deep water exploration. During drilling nearby wells had a number of gas shows from the shallow depth of Pliocene age and post Miocene age equivalent sediments, which were mostly without conventional testing. The fact that this discovery being first of its kind in self-margin area of Basin has inspired the author to present the case study through this paper.

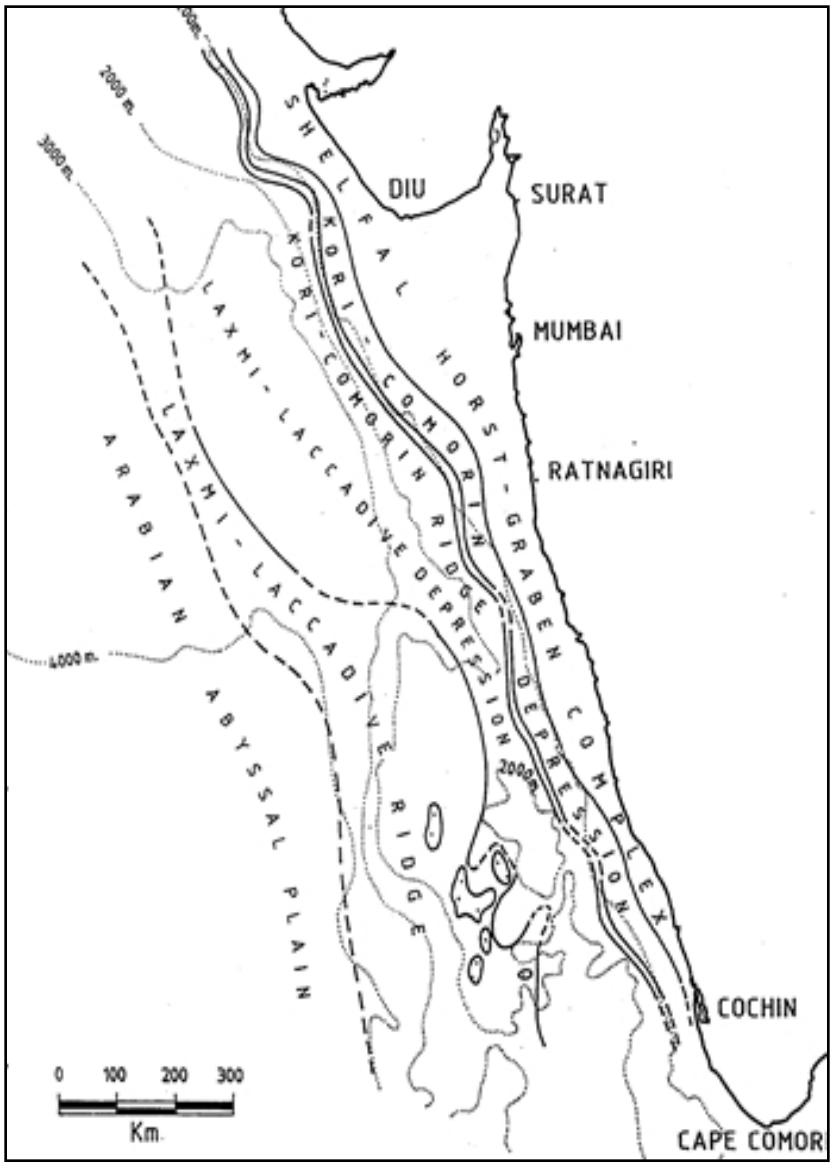
Introduction

The study area falls in west coast of Mumbai, that extends from the present day shelf edge to the distal part of the present day continental slope with bathymetry range from 80m onwards. The tectonic history in brief for this continental margin is as follows, it has experienced two tectonic phases an early rift phase and a Post rift phase.

During Early rift phase from 93Ma years to 50 Ma years, there was a continuous geometric and Isostatic subsidence with volcanism. The rifting was along NNW-SSE-NW-SE and NE-SW direction & resulted in horst-graben-ridges, & detached blocks includes Laxmi ridge, Kori ridge, Western Basement high, and Bombay High, (Fig.1) later from 66Ma years to 65Ma years, valleys with varying widths formed which were filled with volcano clastics derived from Deccan Trap terrain, 65Ma years to 50 Ma years deposition of marginal marine facies in the lows and deposition of carbonates over highs occurred and modest rate of subsidence continued

During Post Rift Phase, a shallow marine Platform stage came into existence from 50Ma years to 40 Ma years and an extensive carbonate platform build up occurred till

the western limit of Laxmi Ridge (Naini and Talwani, 1982, Kolla and Coumes, 1990.), Differential subsidence along faults took place from 40 Ma years till recent ,with occurrence of faulting in the west of Platform area towards end of Middle Eocene, a subsidence of shelf margin depression and the tilting of continental margin during Early to Late Oligocene Period occurred with initiation of deltaic processes on the shelf and shelf-slope system towards west of platform area. The shelf margin depression experienced heavy influx of finer clastics deposited as suspension initially in the lows and later over the whole area, initiation of growth faulting at the outer shelf, due to shelf edge instability, concomitant with further loading.



Study Area

Fig.1: Tectonic Map

Reservoir Geology & Modeling

Twelve wells have been studied across the western coast margin; these are wells A, B, C, D, E, F, G, H, I, J, K, L, and M (Fig 2) .Most of the wells are drilled down to early Eocene and few wells are drilled up to late cretaceous age, the generalized stratigraphy is given in the table 1. The one well which is Gas bearing has flowed biogenic gas from Chinchini formation consisting of sandstone of Pliocene age. The well flowed from two separate shallower reservoirs at depth 500m and 900m, with thickness of reservoir at well level of 6m, and flow rate from ½' choke was around 45000m3/d and 50000 m3/d. The sedimentological study has brought out that the reservoir deposited is of Contourite deposits. The sediments are very fine sands to silt having horizontally laminated traction sedimentary structures with bioturbational mottling and ichnofacies, the clay matrix is almost absent, but calcareous cement present.

During drilling some of the wells had a number of gas shows from the Pliocene and post Miocene age sediments, with high total gas percentage more than 50 %.

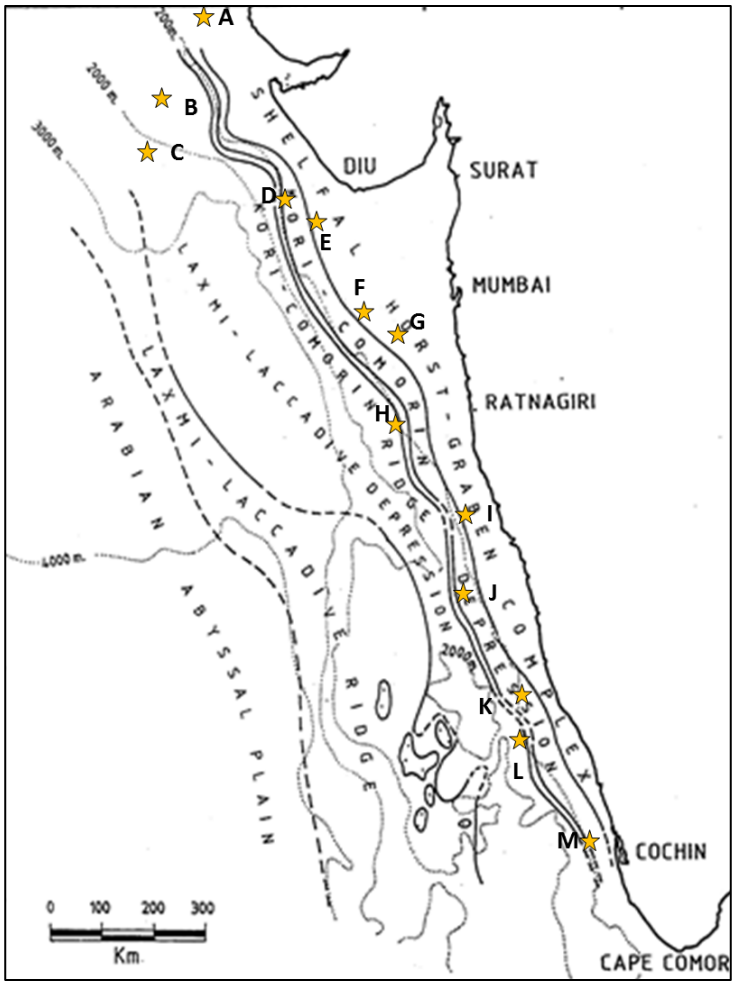

A
B
C
D
E
F
G
H
I
J
K
L
M
DIU
SURAT
MUMBAI
RATNAGIRI
COCHIN
CAPE COMOR
SHELF
LAXMI-LACCADIVE DEPRESSION
ARABIAN
ABYSSAL PLAIN
0 100 200 300
Km

Fig 2

Formations	Age		Lithology	Environment
Chinchini	Late Miocene to Recent		Dominantly Claystone & Shale with thin bands of Siltstone and Limestone	Outer Shelf to Upper Bathyal
Tapti	Miocene	Middle	Dominantly Claystone & Shale	Outer Shelf to Upper Bathyal
Mahim		Lower	Dominantly Claystone & Shale With thin Siltstone layers	
Alibagh	Oligocene	Upper	Claystone and Shale	Outer Shelf to Upper Bathyal
Heera/ Mukta		Lower	Dominantly Claystone & Shale With thin Limestone layers	
Bassein	Eocene	Middle	Limestone with shale streaks	Shallow Marine
Devagarh		Early	Limestone with shale streaks	
Panna (Trapwash)	Paleocene		Trapwash Shale and Siltstone	Shallow Marine
Traps	Cretaceous	Upper	Deccan Trap	

Table 1

Modern contourite have been identified in almost all the oceans around the world and also in in seas and lakes (Faugeres & Stow 1993), the difficulty is to determine potential reservoir facies characteristic of the relation between oceanic bottom current and sedimentary processes of sediment supply and sea level changes (Table 2). Contourite sediments depend on the vicinity of sand and silt rich area under the effects of gravity- or density driven turbulent flows and also depends on slope stability.

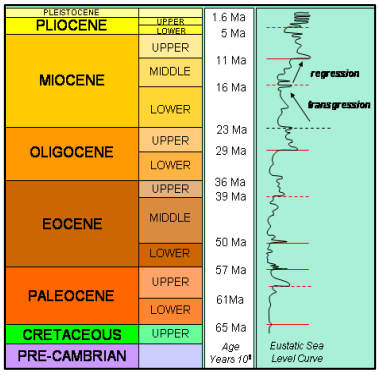


Table 2

The reservoir in the gas bearing well is a shallow-water contourite which seems to be from rocks that accumulated from the shelf edge to the upper slope setting under the predominant action of surface slope boundary currents. Mostly fine-grained sand or

siltstone deposits which are deposits are important as they can act as both seal and reservoir.

The sediment supply seems to be from the northern sector and also from western sector with two major systems - Indus Delta and Tapti Daman Delta via local passageways for sediment transfer. Corresponding to the Slope and Shelf topography it creates formation of eddies which reworks on the contourite sediments (Fig 3). The continental margin topography and physiography plays very important role in controlling the velocity of the contour currents.

Fig 3 Schematic cartoon

A schematic model has been envisaged with assumption that sediment supply is from west considering the gross sand or silt thickness of key wells, overlain the direction of sediment transfer via gullies created during sea level fall by incision of rivers (Fig. 4) with a possibility of reservoir equivalent to Pliocene age, this also confirm by gas shows during drilling of wells. Sand and Silt deposit are frequently worked on by .strong storm fronts, tidal currents, and slope boundary currents, in the form eddies. This creates
off shelf transport of sand by the development of moving sand waves. These sands arrive on the upper slope and are there gets into the slope circulation system. They are redistributed parallel to the isobaths, forming elongated sand-rich deposits (Viana & Faug~res 1998; Viana et al. 2002b).

Fig. 4

Seismic

Contourite deposited in shallow water has some characteristic elements like an adjacent sand-rich shelf with large unidirectional sand waves, shelf edge instability or distal reach of flood-related flows from neighboring rivers and preceding upper slope fine-grained sedimentation. These elements can be observed from seismic data as a channel feature (Fig 5).

In the study area, may be due to very thin sand and silt accumulation with intercalation of calcareous clay stone, it is difficult to decipher.

There are seismic attributes like sweetness which can to highlight sand and silt sediments from surrounding clay stone sediments but, can fail where the thickness of sediments are very less. Contourite deposit can be identified by mapping micro faults and associated DHIs to some extent but fails where ever the reservoirs are very thin.

To identify channels seismic attribute spectral Decomp can be used with rendering of different colours which brings out channel imprints clarity which are act as guidance to equivalent to contourite deposits (Fig 6).

Fig. 5 Seismic line shows the channel features (C) with a moat features (M)

Fig 6 Showing Channels imprints equivalent of contourite deposits at a very shallow depth of 900m approximately.

Fig 7 Showing Channels imprints equivalent of contourite deposits at a very shallow depth of 800m approximately.

Biogenic gas

Gas is now in high demand during recent times which has accelerated the biogenic gas exploration. This type of gas has more than 98% content of Methane with a low in sulphur content and low carbon dioxide content, the gas is dominantly methane and is associated with source rocks that are not thermally mature. Biogenic gas can be migrated or in situ gas dispersed laterally within contourite.

Biogenic gas generation occurs in an anoxic sulphates reducing environment and requires a minimum TOC of > 0.5%, it is produced by the metabolic activity of anaerobic bacteria. Methane generation by bacteria can take place in temperature ranges between 0°C and ~ 75°C, but particular microbes may perform optimally within a narrow temperature band. Edman et al. (2001) discusses a biogenic gas field (Mississippi Canyon 348) in distal, deepwater, low net sand setting in the Gulf of Mexico (2,200 m bathymetry). He suggests that the gas was first generated in turbidites sands, and then concentrated by the formation of gas hydrates. Once the gas hydrates were buried deeply enough to become unstable, they would then have sublimated and exsolved methane which would have migrated laterally and charged up dip reservoirs.

In the gas bearing well (RGL in-house report) methane constituent volume is more than 99% with ethane, propane, butane, helium, carbon dioxide etc. less than 0.1% with gross calorific value around 9000 Kcal/m3.

Conclusion

Biogenic gas entrapment in contourite deposit at shallow depth, less than 1000m is indeed a significant discovery beyond shelf margin. Nearby wells during drilling had

given gas shows, which further encourages exploring western continental margin for contourite sediment reservoirs bearing gas but there are few challenges.
The initial challenge is in the study area to recognize deep-water fine-grained deposits as contourite, most sandy contourite involve sediment transport on the upper
Slope, and via small incision they accumulate in the form of contourite based on the physiological features of the slope geometry, current direction and velocity. Contourite deposit can be identified by mapping micro faults and associated DHIs to some extent but fails where ever the reservoirs are very thin.
To describing the contourite deposit in terms of lateral and vertical extension continuity is also a challenge without high resolution seismic data. Another challenge is the economic viability of biogenic gas accumulation within contourite.

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RGL in-house Report

WCR Gas Bearing Well