Seismic studies of gas hydrate in the KG Basin, East Sea, offshore India

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SUMMARY

India has developed an ambitious research program after successfully unearthing gas hydrate layer at site 10 in Krishna Godavari (KG) Offshore, during first National Gas Hydrate Program (NGHP-1). After studying the result from NGHP-1, second NGHP has been firmed up with an objective to identify the Gas Hydrate prospect for test drilling using seismic data and well analysis in KG offshore areas.

First time a 3D seismic data volume has been studied with objective to identify Gas Hydrate prone areas in Indian water.
To achieve this objective seismic data has been calibrated with well log to identify the Top and bottom of Gas Hydrate Stability Zone. The extent of Gas hydrate is inferred on seismic section by large amplitude (opposite polarity of with respect to Sea bottom) bottom simulating reflector (BSR), which is following the sea bottom and also at places cutting across dipping srata.
In this study, the BSR mapped and then RMS amplitude extracted within window of 100ms above of it. RMS amplitude distribution suggests the variance in Gas hydrate concentration spatially primarily guided by the porosity variation in shape of channel and scroll bar.
Further RMS amplitude extraction 20 ms below BSR suggest the presence of free gas areas associated with Gas hydrate in the down dip towards the regional lows.

The study concludes that there are three to four areas where positive acoustic impedance within GHSZ is available, probably indicative of high Gas Hydrate concentration due to better reservoir condition and may be tested.

Key words: Gas Hydrate, BSR, NGHP, GHSZ, KG Basin

INTRODUCTION

The gas hydrate has a important role in countries like India and Japan where domestic sources of natural gas are very limited. Unconventional gas like Gas Hydrate has significant potential as it represents the large amount of hydrocarbon trapped in the hydrate phase.
The countries showing early interest in Gas Hydrates are- Australia, Belgium, Brazil, European Union, Indonesia, Ireland, Mexico, Norway , Newzealand, South Africa, South America, South Korea, Turky, Ukrine, and Taiwan. Countries with developed Gas hydrate interests are Canada, Chile, China, India, Japan, Russia and United States.

Ambitious research programs have been undertaken in the Mackenzie Delta at the Mallik research site. The program led by Canada and Japan, the 1150m deep Mallik 2L-38 well was completed in 1998. For the first time, cores were brought to the surface from an Arctic gas hydrate occurrence delineating approximately 120m of hydrate bearing section within coarse grained clastic sands.
A second phase of this research program was undertaken in 2002 with a broader five country partnership (Canada, Japan, Germany, USA, India) that completed three additional wells and the first production test. This would be the first time gas would be flared from hydrate.
While the 1998 and `2002 Mallik (S Dallimore et al, 2003) ,gas hydrate research projects enabled many new ground breaking studies, the flow rates were modest. Japan (JOGMEC) and Canada (NRCan) therefore decided to return to the Mallik site in the winters of 2007 and 2008 to initiate a new testing program focusing this time on a full scale production draw down test. These research program has helped to address key issues for naturally occurring gas hydrate prospecting ,formation, occurrence, and stability.

In India ONGC Ltd has been working in the field of gas hydrate exploration since 1997. During the period 1998 to 2003, data of Krishna Godavari Basin (offshore), Cauvery Basin (offshore), Gulf of Mannar and Western offshore were studied for assessing Gas Hydrate prospectivity. These studies provided technical support in formulating NGHP -1 program, wherein 21 sites were drilled/ cored in Indian offshore in 2006. Gas Hydrate layer was encountered at sites NGHP-01-10 in the Krishna-Godavari Basin and at site NGHP-01-17 in offshore of the Andaman Islands (Timothy S. Collett, et al,2008). The findings/observations of NGHP-01 expedition were analyzed/studied by USGS consultant and opined that the KG offshore areas has significant potential and detailed G&G analysis is required to identify the favourable drilling locations.
In view of above, ONGC Ltd. has taken up an area on continental slope where one industry well was available with limited log data. Analysis of well log data and inferred gas hydrate stability zone, several apparent high resistivity (~8- 10 ohms) intervals has been interpreted as hydrate bearing sections. These intervals correlated with seismic data in the search for highly concentrated gas hydrate accumulations in sand bodies using seismic data to map stratigraphic horizon and for amplitude extraction of the event above BSR.
The study in this paper attempted to present identification of unique geophysical response in gas hydrate environment and its spatial distribution that can help to reduce the pre-dill dry hole risk.

AREA OF STUDY

The area of studies falls in Kirshna Godavari basin off the east coast of India (Figure-1). The NGHP efforts in this area coordinated by DGH India for gas hydrate exploration led to delineation and collection of one of the richest marine gas hydrate accumulations yet discovered in the world. Review of seismic data in this area presents best example of BSR also. Probably for this reason area is designated as 'Model Field Laboratory Areas' for Gas hydrate exploration and exploitation.

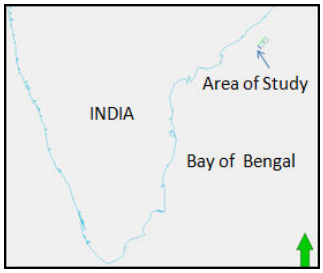

Figure 1. Map showing area of study.

A composite seismic section is shown in figure-2 to depict the geological environment and setup of study area. Well-1 falls in the centre of the study area and lies on the toe of continental slope. The water depth is more than 2500 mts at the well location.

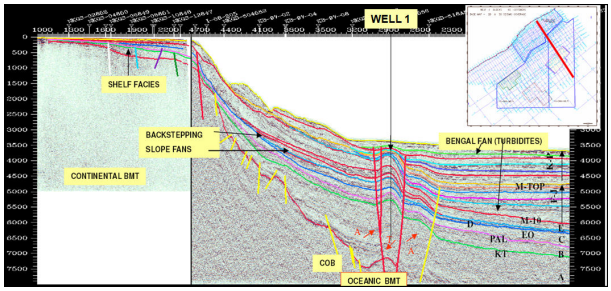

Figure-2. Composite seismic section for Geological set up of study area. (Source WOB ONGC Mumbai)

METHOD

Focus of the present study is to evaluate the 3D seismic data for the potential of finding gas-hydrate-bearing sands. The criteria used conform to a conventional petroleum systems approach to gas hydrate exploration (T. Collett et al, 2010), which include:

- Correlation of seismic and well data of Well-1 using VSP data to identify the top and Base GHSZ.
- Establishment of the extent of the gas hydrate stability zone
- Evidence for gas sourcing and migration into the gas hydrate stability zone (GHSZ)
- Evidence of gas hydrate presence within the GHSZ
- Evidence of occurrence of desired sand reservoir facies within the GHSZ

Seismic method is very effective in understanding of area extent of gas hydrate in an area primarily by mapping of a reflection event that follows the sea bottom, has polarity opposite to sea floor reflection and cut across the geological strata(Christian Berndt et.al,2004). This event is widely known as bottom simulating reflector (BSR). This event is caused by velocity inversion at the base GHSZ where high velocity gas hydrate sediment lies over the low velocity free gas/water sediments. The occurrence of a BSR in seismic reflection data is guiding element in the mapping of gas hydrate prone areas.

Figure-3 is showing part of inline seismic section passing through the industrial well 'Well-1'in the area of study, oriented parallel to sea coast in NE-SW direction. Seismic signature of BSR can be clearly observed (figure-3) and also matches with the depth interval inferred from (high) resistivity response on the log of Well-1.

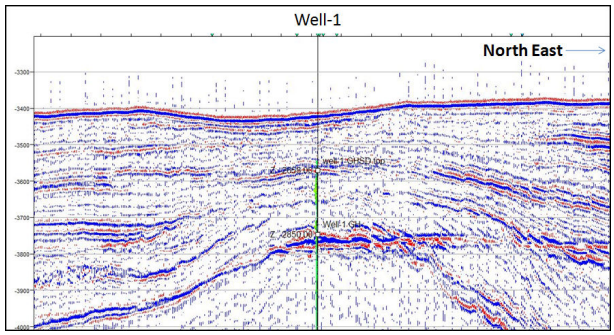

Figure-3. Seismic section showing the correlated Top of GHSZ and BSR from well data. The blue is positive and red is showing negative amplitude values.

As noted above, identified BSR has been mapped for its extent in the area and shown in figure 4. Figure -4 also shows the RMS amplitude distribution above BSR extracted in a window of 100ms. Maximum RMS amplitude response is shown in blue color. At position of Well-1, intermediate RMS amplitude has been observed and found to be in fringes of main gas hydrate zone. The better reservoir facies to hold gas hydrate is lies in the north-east of Well-1.

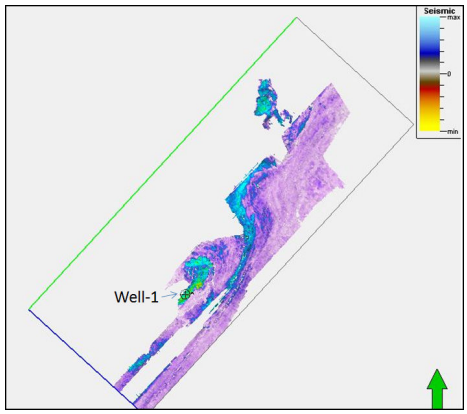

Figure-4. Area extent of BSR shown in figure-3, color scheme shows the RMS amplitude extracted in the time window of 100ms above BSR event.

To understand the evidence for gas sourcing and and migration into the GHSZ, free gas base is mapped, as BSR is the top of free gas. The extent and area distribution of free gas mapped is shown in figure-5.

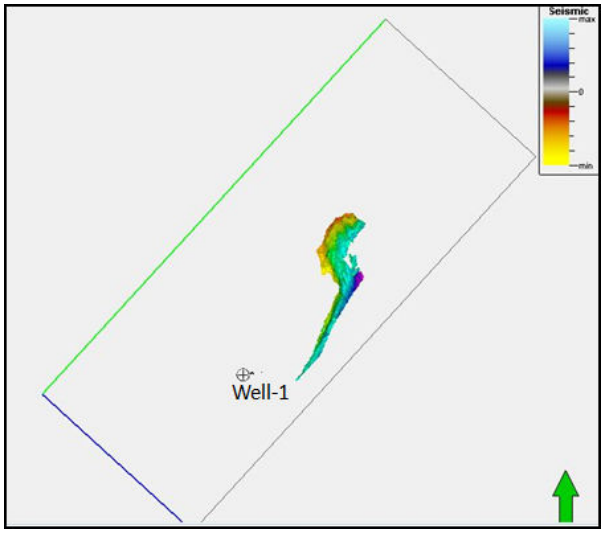

Figure-5. Area extent of free gas below BSR is shown, indicating the presence of minor channel. Color scheme shows the RMS amplitude extracted in the time window of 20ms below BSR event.

On observation of figure-5 free gas zone below BSR is indicating the better reservoir area and concentration of free gas inn eastward of channel like body.
In figure -6 , free gas zone(fig.5) is superimposed over (fig.4) gas hydrate stability zone within 100 ms above observed BSR.

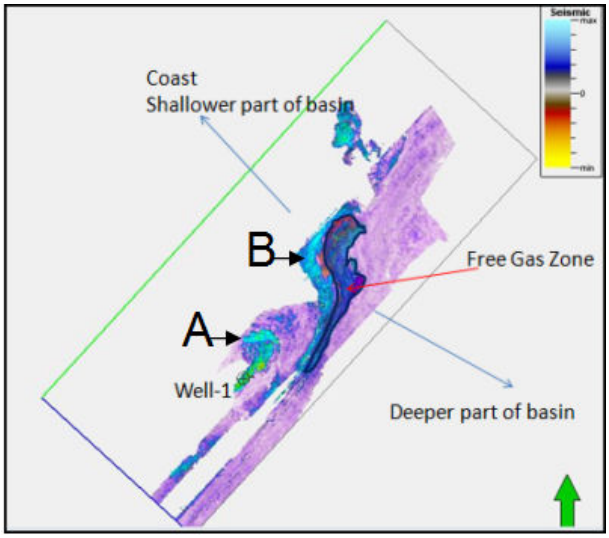

Figure-6. Superimposition of RMS amplitude distribution above(GH) and below (free gas) of BSR.

The observation is as expected as free gas zone is nearer to probable gas generation centre which lies in the eastward downdip of free gas zone (figure-7).
Western part of the free gas zone seems to be area of interest to explore. There are four areas has shown relatively positive and high RMS amplitude. we infer that high RMS Amplitude represents relative high concentration of gas hydrate and may be accepted as Evidence of desired sand reservoir facies within the GHSZ. These reservoir facie can be promising target for drilling.

A random line passing through Well-1, high RMS (within 100ms above BSR) and free gas zone is shown in figure-8 to

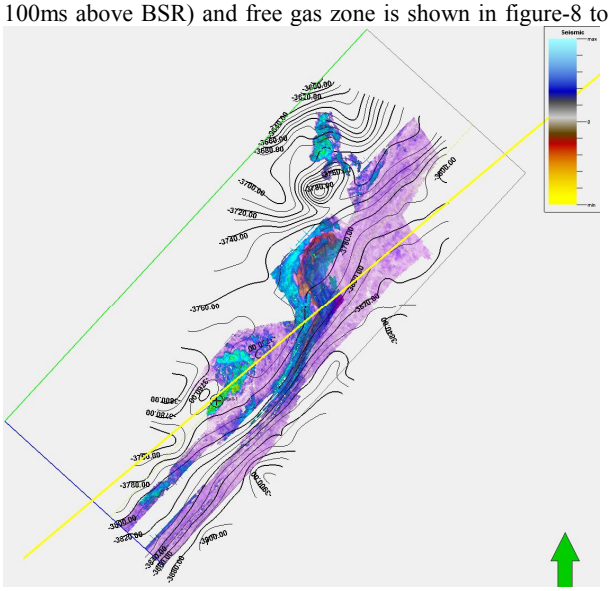

Figure-7. Map showing TWT structural relief

indicate that the a better location than Well-1 is available in north-eastern part.

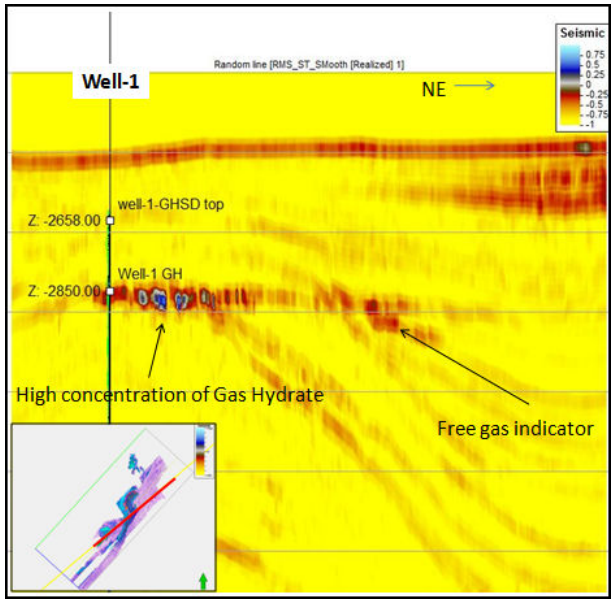

Figure-8. RMS amplitude section of a random line (indicated in inset) indicating the well position, discreet concentration of Gas hydrate, BSR and free gas zone.

CONCLUSIONS

The study suggest that there are evidences for focussed Gas hydrate saturation in several places within BSR demarcated area. However chances for encountering concentrated gas hydrate is in places where pre tectonic structural folding extends in GHSZ (area A in fig.6). It is also concluded that mapping of free gas zone is helpful in understanding the charging fairway and first available reservoir area B in figure-6 can be a good candidate for testing of gas hydrate.

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