



P-97

Gas Hydrate: Prospect and Potential of Mahanadi Deep Water Basin

Anand Prakash*, B. G. Samanta* and Dr. N. P. Singh**

** Regional Computer Centre, P-32 Transport Depot Road, Kolkata 700088*

*** Department of Geophysics, BHU, Varanasi*

Summary

The presence of gas hydrates along the Indian continental margins has been inferred mainly from bottom simulating reflection (BSR) and the gas stability zone thickness map by many scientists (Ramna M.V. et al,2006,Rastogi A et al,1999). Gas hydrate accumulation has been established in KG basin with the help of gas hydrates related proxies inferred from multidisciplinary investigations(Ramna M.V. et al,2006) . In the present study, BSR like features are noticed during the analysis of conventional 3D seismic data of Mahanadi deep water basin. It shows huge aerial extent of the order of 250Sqkm in central part of the area. It shows all the characteristics of classical BSR such as mimicking the seafloor, cutting across the underlying and overlying dipping strata and exhibiting large amplitude but opposite polarity event with respect to sea floor reflection. The BSRs are present to specific area where there is low/depositional centre at Pleistocene level. There might have been biogenic gas generated in that area and under suitable temperature and pressure condition it might have been transformed into hydrates. Coherency inversion of PSTM gathers shows definite inversion of interval velocity across BSR indicating free gas below it. However AVO studies did not show significant anomalies, further data analysis from AVO point of view is required. Full wave form inversion of seismic data is suggested to arrive at velocity-depth profile across BSRs. An integrated study of geophysical, geological, geochemical and microbiological data is proposed to establish the gas hydrate reserve in the area which might be very huge reserve.

Introduction

India's energy requirements mostly depend on fossil fuels, although it has significant coal and hydro resources. Ever increasing demand for sustained industrial growth has forced all of us to look for renewable and alternate energy resources such as coal bed methane in coal seams, shale gas found in shale, and gas hydrate found below or on the ocean floor in the form of ice-like substance. Natural gas hydrates do have the potential of becoming an alternate energy resource due to its huge deposits envisaged worldwide.

Gas hydrates are white, crystalline, ice-like materials comprised of a methane molecule surrounded by a cage of water molecules .The hydrates are mostly methane –rich, but are sometimes associated with ethane, propane, butane, carbon dioxide and hydrogen sulphide. Gas hydrates are found in the permafrost and outer continental margins of the world where the methane concentration exceeds their

solubility limit (Sloan, 1990; Kvenvolden,1998). These are formed at high pressure (8-30MPa) and low temperature (10 to 20degree Celsius) in shallow sediments, and are stable up to a few hundred meters below sea floor. Methane trapped in hydrates and free gas below the hydrates bearing sediments is huge .An estimated reserve of 7x100000 Tcf methane is trapped in gas hydrates around the world(Kvenvolden,1993) has prompted a recent increase in hydrate research worldwide. India has also began active research in establishing gas hydrate reserves in east and west coast by collecting geophysical, geological, geochemical and microbiological data under its Natural, Gas Hydrate Programme (NGHP) initiated and funded by Ministry of Petroleum and Natural Gas, Government of India.

Gas hydrates are mostly identified by mapping a bottom simulating reflector (BSR) on seismic section. The BSR is recognized based on its characteristic features such as (i) mimicking the shape of sea floor as BSR follows isotherms



Gas Hydrate: Prospect and Potential of Mahanadi Deep Water Basin



which are nearly parallel to the morphology of sea floor as opposed to following a stratigraphic horizon, (ii) cutting across the underlying dipping strata and (iii) exhibiting large amplitude but opposite polarity events with respect to the seafloor reflections. Presence of gas hydrates reduces the permeability of the sediments and hence traps free gas underneath. Thus the BSR is an interface between gas hydrates-bearing sediments above and free-gas saturated sediments below, and is often associated with the base of the gas hydrate stability field. The BSRs may not be continuous but patchy events indicating the hydrate layer above it may be gradational upward and the free gas layer may be gradational downward. Most of the gas hydrates, world over have been inferred from the BSR and Gas Hydrate Stability Zone (GHSZ) thickness map. The Gulf of Mexico, Blake Ridge, Cascadian Margin, McKenzie Delta and Nankai Trough are some of the good examples of this category. On the other hand, some of the BSR proven areas on drilling yielded no gas hydrates. Some of the areas covering Blake Ridge, Nankai Trough and Goa offshore area, and west coast of India are examples of this category.

Again, gas hydrates have been reported at many places in the world without BSR (Westbrook et al. 1994; Wood and Ruppel, 2000; Ashil et al. 2002). This implies that all inferred BSRs are not necessarily indicate the presence of gas hydrates, sometimes lithology gives such pseudo-reflections. Presence of double BSRs on seismic sections is also reported by Posewang and Mienert, 1996 and that cause an enigma to the hydrates stability zone calculation. Therefore other proxies – geochemical, microbiological etc. are to be looked into for ascertaining the gas hydrates accumulation. In addition to geophysical anomalies such as BSRs, pockmarks, gas up thrust zone, vents, blanking zones, etc. other geochemical and microbial proxies are required to be studied in order to mitigate the risk in drilling a dry hole.

Almost all the giant oil fields- Gulf of Mexico, Caspian Sea and Mediterranean Sea are also seen associated with gas hydrate accumulation in the upper few hundred meters of sediments. The permafrost regions (Siberia in Russia, McKenzie delta in Canada and Alaska) known for their conventional hydrocarbon reserves are also associated with gas hydrates deposits. Therefore it is believed that the areas of conventional hydrocarbon prospects could also serve as locales of gas hydrate deposits provided geological formations meet the requirements of high pressure and low

temperature. Some of the offshore basins such as Saurashtra, Mumbai, Kerla-Konkan, Krishna-Godavari, Cauvery and Mahanadi along the Indian Continental margins are well known petroliferous basins. National Institute of Oceanography (NIO) has prepared a map for gas hydrate accumulation along Indian continental margins (Figure-1). Gas hydrate stability zones thickness map are prepared based on available data on bathymetry, heat flow, seabed temperature and geothermal gradient etc. by many Geoscientists (A. Rastogi, et al. 1999, M. V. Ramna et al., 2007) within the EEZ of India. Figure -2 shows one such map. Geophysical, Geochemical and Microbiological proxies observed in east coast of India have suggested a strong indication for gas hydrate deposits in KG, Cauvery, and Andaman basins. The drilling by JOIDES Resolution drill ship under NGHP Expedition-1 in KG basin has confirmed presence of massive gas hydrate accumulation (>80m thick) in KG basin.

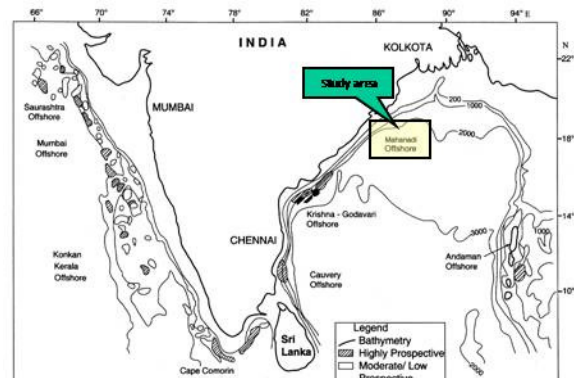


Figure-1. Map depicting prospective area for Gas Hydrate along India continental margins (after M.V. Ramna, et al. 2006)

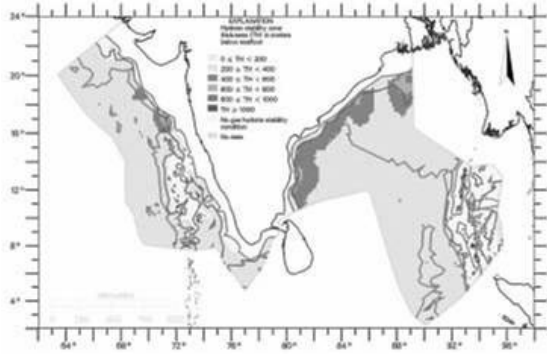


Figure-2. Gas hydrate stability zone thickness map (in meters) prepared using bathymetry heat flow and sea bed temperature, (after M.V. Ramna,2007)

In Mahanadi deep water basin, BSR like features are reported in many areas but a thorough analysis of data for other geophysical, geochemical and microbiological proxies are needed to establish the presence of gas hydrate accumulation. Geological preconditions such as high rate of sedimentation (20-40cm/KYrs) adequate depth and low temperature coinciding with BSR indicate gas hydrate accumulation in Pleistocene sediments in Mahanadi deep water areas. In the present study, 3D seismic data in Mahanadi deep water areas are studied to look for BSR like features which are present most conspicuously in a certain part of the area. Velocity and amplitude (VAMP) study of the BSR is done and velocity inversion is observed. The AVO study of the BSR is not that encouraging.

Geological Set-up

The Mahanadi basin is among the several sedimentary basins developed along east coast of India as a result of rifting and break-up of Gondwana land during Jurassic period. This cover an area of over 50000 Sq.Km , of which nearly one fourth is in onshore and the rest is offshore. Tectonically, these basins are developed around a triple junction between the NE-SW trending east coast of India (which represents an Atlantic type passive continental margin) and the NW-SE trending Mahanadi graben within the Indian shield.(Fuloria R.C. et.al. , 1992). The basin is separated from KG basin by 85°E Ridges. Major tectonic features are shown in Figure-2. The hydrocarbon prospects of offshore basin are rated good as it belongs to a petroleum province (Jagannathan C.R. et.al, 1983).. Deep-

water part of Mahanadi basin attracted much exploration attention due to its proximity to the deep-water area of KG basin having proven huge Gas reserves as well as due to recent gas discoveries in the area.

Paleogene and Neogene section in deep-water basin exhibits channel complex; highly sinuous often stacked vertically due to shifting of depositional axis both in space and time (Nath. et. al.,2006). A sinuous channel-levee complex often results in submarine fan lobes towards deeper part of the basin. Incised valley and valley fill sequences are also prevalent during Paleogene and Neogene periods.

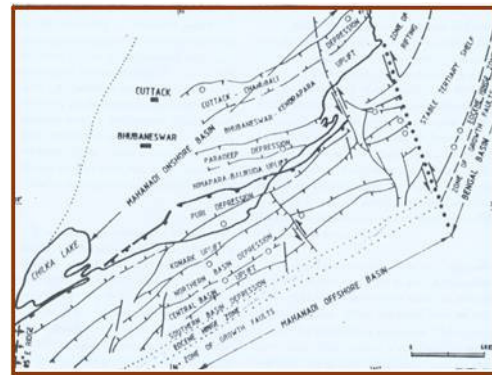


Figure 3. Tectonic map of Mahanadi basin

Data and Methodology

The area is covered by 3D seismic survey and standard 3D data processing has been done. Table-1 shows the processing sequence. During the data analysis, BSR like features are observed on the seismic sections. Special processing attempts such as very close velocity analysis on PSTM gathers to arrive interval velocity and AVO analysis of BSR are also made to study more closely these BSR like features. An aerial mapping and delineation of these BSRs is made.



Table-1..Processing Sequence

Bad SP and Traces editing, Band Pass Filter
Automatic despiking and Navigation data merge
Spher div. Correction ,Swell Noise attenuation
Radon linear noise attenuation
Designature to min. phase and reverse polarity
Tidal correction
Deconvolution ,Rdaon anti-multiple
Flex Binn., Gun/cable static correction
Spher div. corr. removal
Kirchoff PSTM for velocity analysis
Velocity Field generation
Full Volume Kirchoff PSTM
Residual Velocity analysis
Final Stack,Final Scalin g/filtering

Result and Discussion

The seismic section (Figure-4) show the presence of BSR like anomalous reflections 300-400 ms below the seabed. These BSR like features are distinct and follow the characteristic features (i) mimicking the seafloor;(ii) polarity reversal;(iii) cross-cutting the lithological formations; and (iv) blanking above and below the BSRs. The BSR reflections are very strong at some locations and feeble at other places. The reflection strengths may be attributed to the saturation of free gas beneath it as well as gradation of gas hydrate upwards.

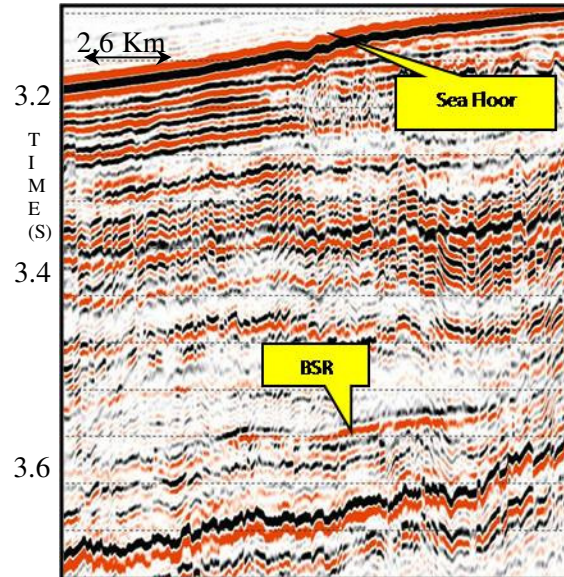


Figure-4. Seismic Section Showing BSR

It is also very important to note that these BSRs are present in areas of low at the Pleistocene level, indicating thereby that gas hydrate accumulation may be restricted to this depositional center (Figures-6,7). The sedimentary thickness is more here and methane gas generation might be restricted to this depositional center. As we go towards eastern part of the area we do not observe any BSR like reflections although seafloor depth is of the same order (figure-8). If we calculate gas hydrate stability zone thickness with these BSRs (Figure-5) it comes out of the order of 300-400m. Rastogi et al., 1999 have estimated the GHSZ thickness of Deep Indian Offshore areas using geothermal gradient, seabed temperature and bathymetry data using GIS based approach which shows that in Mahanadi GHSZ thickness is of the same order (300-400m).The BSRs are mapped and delineated throughout the area and the areal extent of these features is of the order of 250Sqkm which is quite big an area



Gas Hydrate: Prospect and Potential of Mahanadi Deep Water Basin

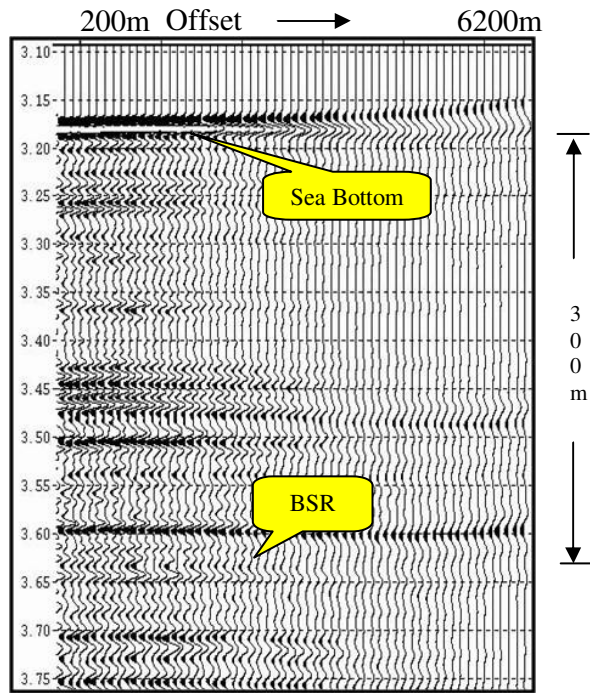


Figure-5 PSTM gather Showing BSR polarity opposite to Sea Bottom reflection

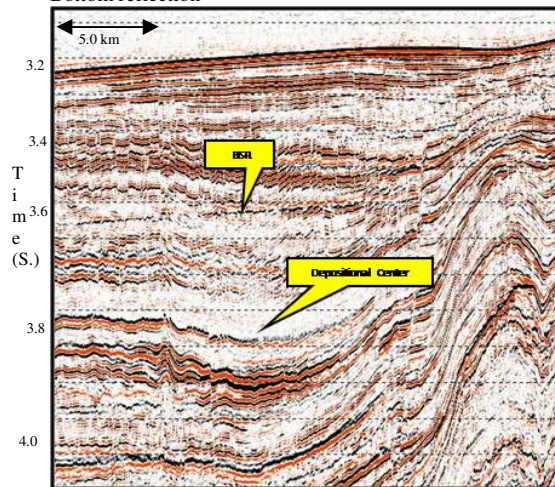


Figure-6 Seismic Section Showing BSR and deposition centre at Pleistocene level (Inline-A)

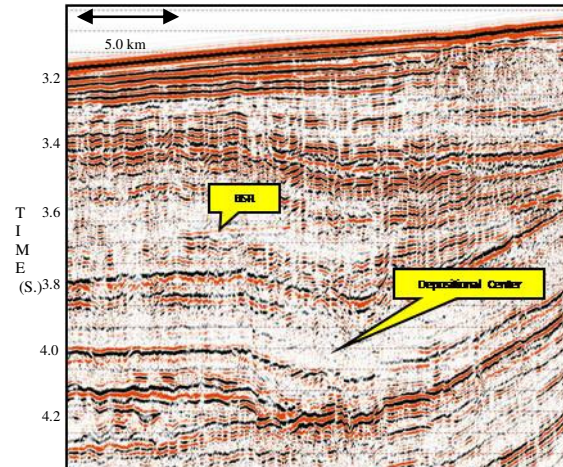


Figure-7 Seismic Section Showing BSR and deposition centre at Pleistocene level (Inline-B far away from B)

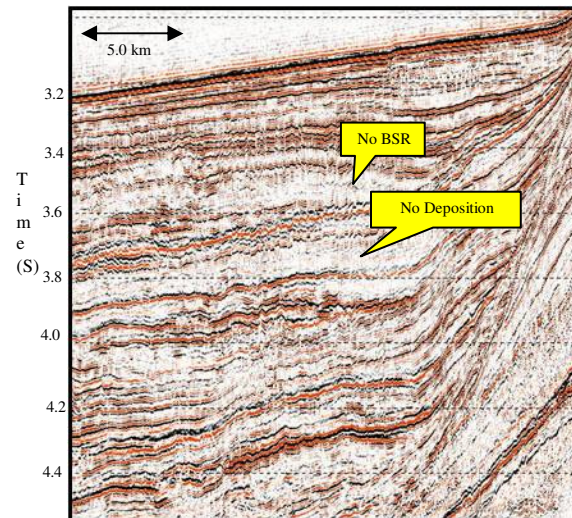


Figure-8 Seismic Section Showing no BSR and no deposition at Pleistocene level

Coherency inversion of PSTM gathers indicated a velocity inversion at the base of the BSR. The interval velocity reduces to 1520m/s below the BSR from 1750m/s above BSR. The interval velocity of the sediments having gas



Gas Hydrate: Prospect and Potential of Mahanadi Deep Water Basin



hydrates above BSR is on the lower side than it is usually encountered in the classical cases. The reason could be the basic sediments may be silty-clay or clayey-silt. Figure-8 shows the reduction in interval velocity below BSR

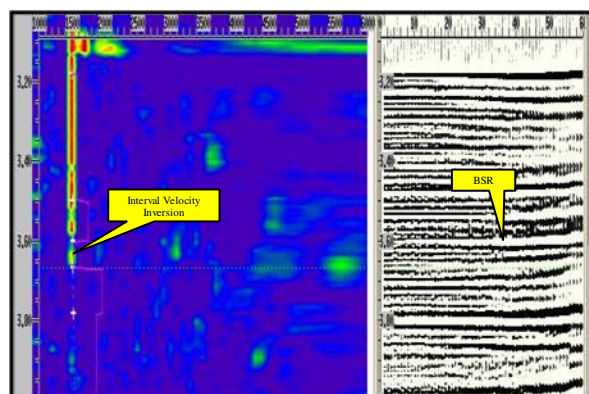


Figure-9 Velocity panel showing Interval Velocity Inversion below BSR

AVO analysis of BSR did not result any significant anomaly. Generally, BSR show increase in amplitude with offset. Phase change is also observed at long offsets. In figure- 10 , BSR shows insignificant increase of amplitude with angle whereas there is significant decrease of amplitude of sea bottom reflection with angle. Further detailed AVO studies of BSRs are required.

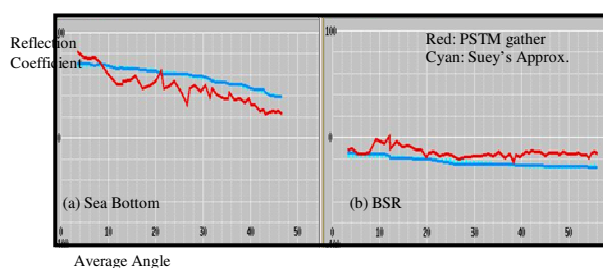


Figure-10 AVO response (a) Sea Bottom Reflection (b) BSR

Conclusions

The BSRs observed in Mahanadi deep water area suggest high probability of gas hydrate accumulation in the central part of the area. The BSRs observed in the area fulfill all

the characters of a classical case of gas hydrate accumulation, such as polarity reversal, cross cutting the formations and velocity inversion across BSR, blanking above and below BSR. Delineation and mapping of BSR indicate big area of possible occurrence of Gas Hydrate. The aerial extent is of the order of 250 Sq. Km.

However an integrated study of geophysical, geological, geochemical and microbiological data is required for the exploration of gas hydrate in the Mahanadi deep water area.

Note: The concept and ideas of this paper is solely of author's view.

References

Fuloria R.C.,1992,Stratigraphy, structure and tectonics of Mahanadi offshore basin; Geological Survey of India Spl. Publication No. 29

Nath P. K., Samajdar Chandan , Mukhopadhyaya ,2006;Depositional system of Deep water setting for understanding of hydrocarbon play with reference to Mahanadi basin.

Ramna M.V. Ramprasad T., Desa, M sathe M.V. and Sethi A.K.; 2006, Gas hydrate related proxies inferred from multidisciplinary investigations in the Indian offshore area; Current Science Vol.91 No.2

Ramna M.V. Ramprasad T.,Raju K.A.K. and Desa,M ; 2007; Occurrence of gas hydrates along the continental margins of India, particularly the KG offshore basin; International Journal of Environmental Studies, Vol 64,No.6,675-693

Rastogi A., Deka B.,Bhattacharya G.C., Ramprasad T. et al.; 1999, Gas hydrate stability zone thickness map of Indian deep offshore areas- A GIS based approach; PETROTECH-99, 489-494

Sain Kalachand, and Gupta H.K., Gas hydrates-Future Potential Source of Energy in India, Glimpses of Geosciences Research in India, pp 244-246



Gas Hydrate: Prospect and Potential of Mahanadi Deep Water Basin



1. Sloan Jr E.D. ,1998, Gas hydrate: reviews of physical/chemical properties: Energy and fuels,12,191-196
2. Kvenvolden,K.A.,1993,Gas Hydrate- Geological perspective and global change: Review of Geophysics 31,173-187
3. Jagannathan C. R. et al ,1983, Geology of the offshore Mahanadi Basin, Petroleum Asia Journal
4. Posewang J. and Mienert J. ,1996 The enigma of double BSRs: Indicators for changes in the hydrate stability field, Geo-marine Letters V19,157-163

Acknowledgements

Authors are grateful to ONGC for giving permission to use the data. Authors express their sincere thanks to Shri D. K. Pande, Director(E) Sri A.K.Biswas, Basin Manager for his kind support and encouragement. We acknowledge the guidance & suggestion and continuous encouragement by Sh. M. Das, GM -HGS to carry out the study. We sincerely thank to Sh. A. K. Sarkar, SG(S) for his technical support.