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Potential Natural Gas Hydrates Resources in Indian Offshore areas

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The first indication of presence of gas hydrates in Indian Offshore dates back to 1984 when Oil and Natural Gas Corporation Limited (ONGC) (Chopra, 1984) identified BSR for the first time in Andaman offshore. Exploratory assessment for the possible presence of gas hydrates in Indian Offshore areas by ONGC and National Institute of Oceanography (NIO) sparked the interest in natural gas hydrates. The Indian Geophysical Union (IGU) Conference held in 1995 at National Geophysical Research Institute (NGRI), Hyderabad, India deliberated the topic of Indian Gas Hydrates resources. Subsequently, Ministry of Petroleum & Natural Gas (MOP&NG), Government of India established an expert committee to recommend the steps to be undertaken for exploration and development of gas hydrate resources in India. Based on the recommendations, a National Gas Hydrate Programme (NGHP) was instituted in 1997. Simultaneously, ONGC, GAIL and Directorate General of Hydrocarbons (DGH), (oil industry), and the national laboratories such as NIO and NGRI initiated in house R&D activities related to gas hydrates for mapping and evaluation of gas hydrate resources in Indian Offshore. To give further thrust to the gas hydrate related activities, MOP&NG reconstituted the NGHP in the year 2000. The ultimate goal of the programme was to achieve maximum self-sufficiency in hydrocarbons through tapping this unconventional source of energy. The roadmap is in place to achieve the commercial production of gas from gas hydrates beyond 2008.

Large amount of Multi-channel Seismic reflection data was acquired by oil industry for exploration of hydrocarbon in the Indian Deepwater basins, beyond 400m isobath. These data were examined for BSRs, blanking above BSRs, polarity reversals etc (geophysical proxies of gas hydrates). A qualitative map prepared based on the inferred BSRs brought out a deepwater area of about 80,000 sq.km unto 3000m isobath as favourable for gas hydrate occurrence (Kuldeep Chandra et. at. 1998). Methodology for reprocessing of seismic data was evolved during 1997 to infer BSRs (gas hydrates) by ONGC in collaboration with University of Victoria (UV), Canada. Subsequently several seismic line segments from the Indian offshore areas were reprocessed. Clear BSRs cutting across the sedimentary strata supported with interval velocity inversion in Krishna-Godavari deep offshore Basin were observed. The swath bathymetry maps generated for Eastern and Western offshore areas depict the seafloor morphology. Based on the encouraging results of these initial studies, further reprocessing of the seismic data was carried out by ONGC in a selected area in the Krishna-Godavari Basin. (Figure 1)

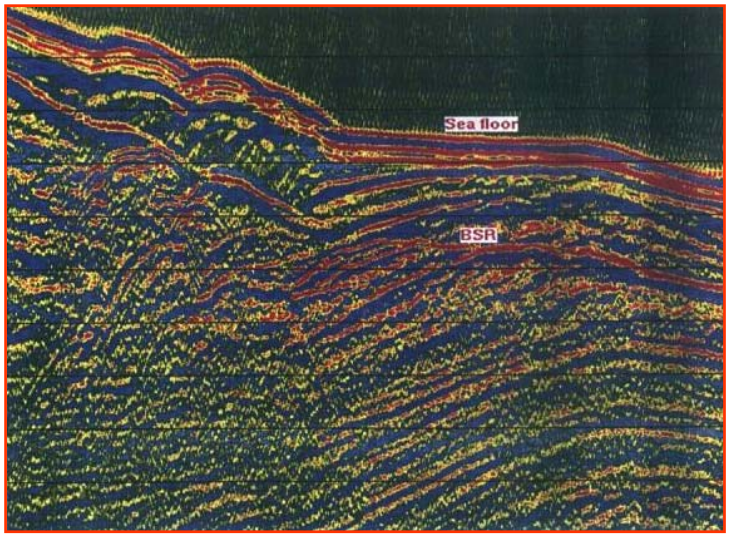

Figure 1 :Seismic Section from K.G. Basin in East Coast Showing BSR

Geophysical proxies in Andaman Sea

The Directorate General of Hydrocarbons (DGH) simultaneously carried out gas hydrates related studies in collaboration with Western Geophysical and LARGE of Russia, using MCS data that was acquired for hydrocarbon exploration in the Andaman deepwater area during the three different campaigns in 1996-97, 1999 and 2001. The BSRs are seen cut across the upper Miocene to Middle Miocene strata, and broadly follow the seabed topography. The processed MCS data show the indications of free gas below the BSRs and the corresponding seismic signatures resemble like the anticlinal closures. It was also observed that the BSRs appear to be serving as the cap for the underlying free gas. The BSRs were mapped over an area of about 3000 sq.km. Seven gas hydrate-bearing prospects have been identified below the seabed in the water depths of 850m to 2000m. High amplitude BSR Zones are parallel to central half graben feature of the fore arc basin. The flat spot identified in few structural prospects beneath the BSRs, suggests possible gas water contact (Figure 2).

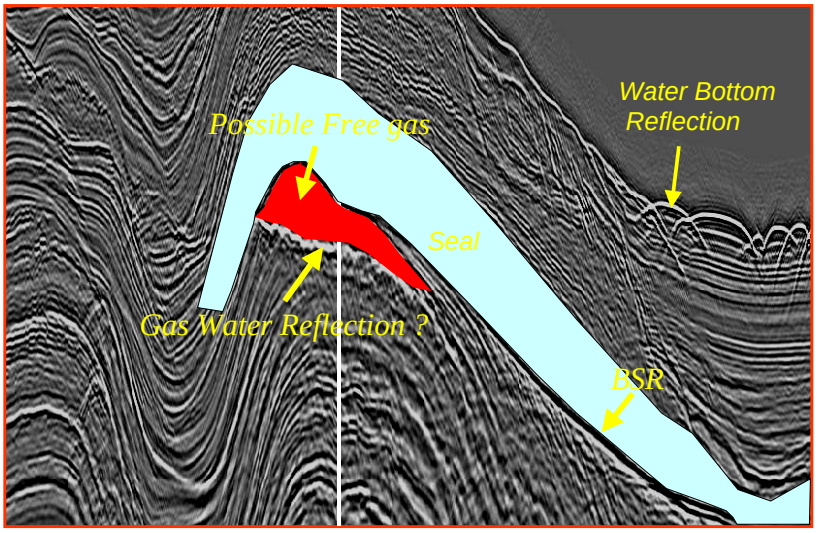

Figure 2: Gas Hydrate as a seal to free gas in Andaman Offshore

Pre-stack Genetic Algorithm (GA) inversion, a full waveform inversion method, was carried out by the Western Geophysical to confirm the seismic anomalies. The GA pre-stack inversion extracts Vp, Vs, density and Poisson's Ratio (PR) from non-NMO corrected gathers were processed for AVO using pre-stack time migration and non-muted processing sequences. Results of post-stack hybrid inversion indicate that low PR anomalies generally associate with BSRs are not strikingly obvious. However, localized anomalies were observed at few locations (Figure 3).

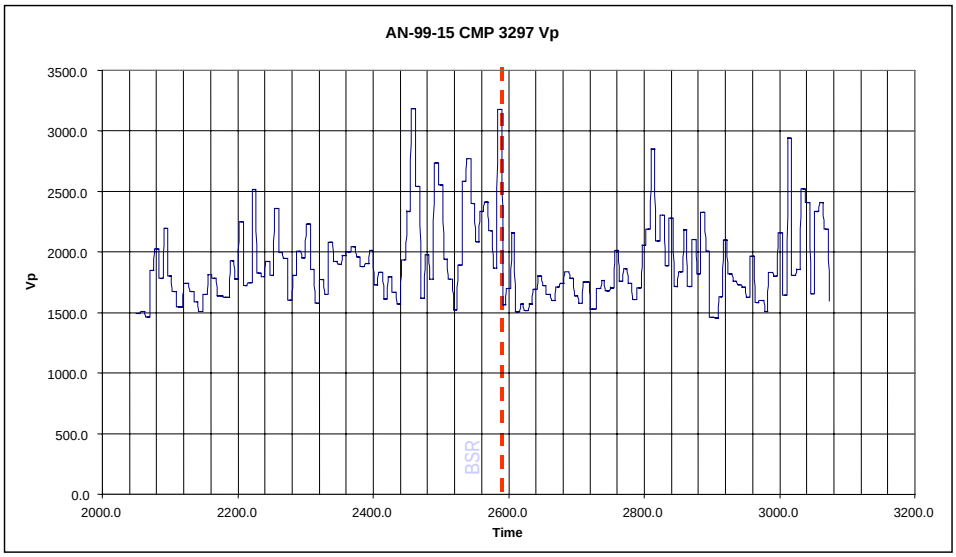

Figure 3 : GA Inversion - P Wave Velocity in Andaman Offshore

The GAIL (India) Ltd., one of the National Companies in collaboration with the national laboratories such as NIO and NGRI carried out gas hydrates studies using about 4300 lkm of MCS data pertaining to Kerala-Konkan Basin in the west coast, and inferred BSRs which are strong, moderate and week. Based on the results of multidisciplinary studies carried in collaboration with DGH, ONGC, GAIL and NIO, three offshore areas i.e. Krishna-Godavari basin in the east coast, Kerala-Konkan basin in the west coast and Andaman offshore area were delineated for further geoscientific investigations to infer more proxies related to gas hydrate before coring/ drilling of the gas hydrate bearing sediments. The Swath bathymetry, deep tow digital side scan sonar images, Chirp Sonar, Gravity, Magnetic, geological, geochemical and Microbiological data were generated in two phases during 2002-2003 as a first step to understand the shallow geology of the areas. The gravity cores and water samples collected were analyzed for physical properties, gas chemistry and microbial signatures in the east and west coast areas. The high-resolution sparker data, which was earlier planned could not be acquired due to malfunctioning of equipment. Efforts are being made to acquire this data and use it to infer BSRs before coring of gas hydrate sediments in the first quarter of 2005.

Multidisciplinary investigations in Krishna-Godavari Basin

Analysis and interpretation of the geophysical, geological, geochemical and microbial data have revealed the presence of several gas hydrate proxies in the east coast area. Deep Tow Digital Side Scan Sonar images depict the presence of clusters of pockmarks and carbonate reef like features on seabed. The multi-frequency Chirp Sonar and 3-5 KHz Sub-bottom profiler

records depict the penetration up to 40-60m below the seabed and several gas escape features and gas plumes unambiguously. Sometimes, the seabed is seen affected by gas up trust and in some other cases the sub-bottom reflectors are affected by gas masking. Blanking or disappearance of reflector is commonly seen in the KG basin. The high resolution Swath Bathymetry map depicts macro and micro bathymetry features more conspicuously. A WNW-ESE trending positive topography feature (sedimentary ridge) appears to be similar to Blake Ridge is a conspicuous geomorphic feature, which needs to be investigated thoroughly. The crest of the ridge rises from the surrounding water depth of >1400 to <900m. The width of the ridge is about 10 km. In northwestern part of the study area, a fault controlled fan like geomorphic feature is also observed.

Study of 5 m long gravity cores reveal the variation of methane concentration in the top sediments between 0 and 2.27nm, whereas the highest concentration of >158nm was observed in the bottom sediments of one of the cores. The methane enrichment trend with the core depth was observed at 23 out of 76 sample locations. On the other hand SO_4^{2-} reduction trend with core depth was noticed at more than 48 out of 76 core locations. The Cl^- profiles do not depict much variation with depth. However, low concentration of Cl^- (~500NM) is observed at several locations. The Organic Carbon (TOC) concentration (Wt %) varies between 0.35 and 1.35 at middle level and a high concentration of > 2.5 were at one location. XRD and SEM studies indicate the presence of authigenic carbonates in subsurface layers, which might have formed in presence of the methane gas rising from the deeper layers.

'Ba' enrichment of nearly 5 to 6 times is observed in bottom of cores compared to core top. These elevated 'Ba' concentrations at the core bottom suggest Barium front phenomenon. The observed 'Ba front' serves as precursor to predict the occurrence of methane below the sulfate reduction zone. The 'Ba' enrichment trend has been noted at more than 25 locations. These observed trends of methane enrichment, sulfate reduction and Cl^- depletion with depth appear to be related to the processes of 'Sulfate Methane Interface' (SMI) though this needs further investigation through analysis of longer cores.

The microbiological studies revealed presence of SRB_r, SRB_f and NRB in appreciable quantities at the bottom layers, probably a strong indicative of continuous supply of methane from the subsurface layers. Integration of geophysical, geological, geochemical and microbiological data results suggests that KG basin is highly conducive for gas hydrate occurrence. This belief is further strengthened by the presence of several gas hydrates layers through the recent drilling activity by private companies and ONGCL, and MWD logs.

Multidisciplinary investigations in Kerala-Konkan Basin

Similar multidisciplinary studies were carried out in Kerala-Konkan offshore basin in west coast. A positive NW-SW trending topographic feature rising from 2400m from surrounding seafloor at 3000m in the central part of study area is noteworthy. The seafloor images obtained from deep tow digital Side Scan Sonar system are devoid of pock marks and gas escape features and the multi-frequency Chirp Sonar and 3.5 KHz sub-bottom profiler data are devoid of gas escape features, excepting some micro features resembling as the gas escape feature. On the other hand, some seismic sections show the presence of BRS like features, and the analysis of core samples indicate the presence of methane enrichment, sulfate reduction and chloride depletion trends with core depth. The geochemical and microbiological parameters show TOC increase at 10, $CaCO_3$ increase trend at 9, CH_4 enrichment at 12, Cl^- depletion at 10 and SO_4^{2-} reduction at 11, SRB_r minimum count at 19 and SRB_f appreciate quantity at 10 locations respectively.

Inferences

Synthesis of multidisciplinary data results indicate that Kerala-Konkan basin area in west Coast is also a promising prospect from gas hydrate occurrence point of view, but needs intense studies including acquisition of high resolution sparker data and collection of long cores (>20 m) to confirm SMI. Based on studies carried out so far on gas hydrate exploration, the probable presence of gas hydrates in the Krishna-Godavari Basin in the east coast and Andaman offshore are very high when compared with that of Kerala-Konkan basin.

The NGHP, under the guidance of Government of India decided to carry out drilling/ coring at 10 locations in first quarter of the year 2005 of the possible gas hydrate bearing sediments in the above three Indian Offshore areas to characterize the gas hydrate bearing sediments and to asses the resource potential.

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