Challenges during Drilling through Gas Hydrate Bearing Zones (GHBZ)

Integration of Seismic While Drilling (SWD) technology principles with Seismic Wave Attenuation of Gas Hydrates to detect Gas Hydrate Bearing Zones in prior

[1]Praveen Gontena,[2]M.V.V.S.Anu Prakash,[3]P.Mohan Satya Murthy

[1]Research Scholar,[2]Assistant Professor,[3]Research Scholar
[1]Department of Petroleum Technology,
[1]Aditya Engineering College (A), Surampalem, India

Abstract : The demand and supply of the energy was not in balance as the Energy demand was increasing but the resources were depleting**.** Oil and Gas industry is breaking its boundaries and reaching all the locations, even locations which are previously depicted as inaccessible to explore the hydrocarbons. In the last 50 years, drilling in Offshore was developed at an alarming rate. With the increasing technological advancements, industry was raising its bar and also planning to drill at water depths greater than 12000 feet. Drilling in offshore was challenging operationally, climatically and also economically. This study has been undertaken to examine the challenges during drilling through Gas Hydrate Bearing Zones (GHBZ) as it was a common problem in marine conditions. Gas Hydrates will cause problems like wellbore instability, tubular plugging & well kick etc., which makes loss in economy and added rig time. To address my idea of application for zones bearing gas hydrates in conventional oil & gas drilling wells is with the integration of Seismic While Drilling (SWD) and Seismic Wave Attenuation properties of Gas Hydrate Sediments, to detect the gas hydrates prior to the entering of hydrate accumulated formations and also to correlate the depth of gas hydrate bearing zone with Bottom Simulating Reflector (BSR). As the Natural Gas Hydrate Zones are developing and changing the industry's perspective as conventional zones for producing Natural Gas commercially, Seismic While Drilling using Elastic Wave Attenuation will acts as backup tool to detect and to confirm the Gas Hydrate Bearing Zones in future.

***IndexTerms* – Gas Hydrate Bearing Zones, Seismic While Drilling, Bottom Simulating Reflector.**

I. INTRODUCTION

Easy Oil has gone, the sentence depicts that there is no Oil left which can be explored and produced easily. The first oil well was stuck in the year 1859, known as "Drake Well" located at Cherrytree Township, Venango in northwestern Pennsylvania. This well was completed at a depth of 69.5 foot (21.1 meters), which is referred as first commercial Oil Well. It's been 160 years since the drake well completed and during this course of period oil industry had developed and extended to deeper depths and inaccessible locations etc. The deepest Oil well ever drilled was Deepwater Horizon (Gulf of Mexico) with a vertical depth of 35,050 ft (10,683 meters).

The Journey of Oil Industry from 69.5ft to 35,050ft has come a long way, and industry had seen lot of ups and downs Economically, Environmentally, Geopolitically and also in Science and Technology. We had reached and crossed the Oil peak production of its lifetime in the year 2011, so it's time to concentrate and develop some new technologies which would improve the Production of Oil and Gas with the present consumption to get ourselves back into the Energy frame.

Oil consumption was increased to 1.4 million barrels/day and Natural gas consumption was increased to195 billion m^3/day (Source: BP Statistical Review 2018). To increase the production, we should access the areas which are presently framed as Inaccessible (Himalayas, Mountain Regions, Forests, Deep Offshore and also extra terrestrial places).

For existing wells, to increase the production we have technologies like Artificial Lift Techniques, Improved Oil Recovery Techniques (IOR). For Cost management, Reaching Inaccessible locations and for exploring thin reservoirs we have Directional Drilling (Multilateral Wells, Re-entry drilling, Horizontal Well technology, Staircase drilling, Pad drilling, etc.). Finally Intelligent Well Completions, which deals with completion designing to deliver better optimization & monitoring of Production from a well.

The main area of interest for industry is to focus on Deep Offshore regions (exploration and production extended deep sea), which is the present trend in industry and also the future. All the above mentioned technologies can be applied to the wells drilled in offshore region, which leads to the increase in Ultimate hydrocarbon recovery.

But drilling offshore is challenging as there are lots of problems operationally, economically, climatically etc. Related to operations: Pipe sticking, loss of circulation, hole deviation, drill pipe failure, borehole instability, mud contamination, producing formation damage, hole cleaning, hydrogen sulfide bearing sediments, shallow free gas zones, and most importantly **Gas Hydrate Bearing Zones (GHBZ)**. Economically, drilling offshore was costly compared to drilling onshore and also the equipment used in offshore is sophisticated and complex. Related to Climate offshore drilling was difficult as the environments are harsh and the weather conditions are severe (like storms, high wave actions) which would challenge the functionality of Rigs.

II. GAS HYDRATES

Gas hydrates, or methane hydrates, are created when methane is frozen in the molecular structure of ice. They are classified as clathrates, compounds formed by the inclusion of one molecule (CH_4) within cavities in the crystal lattice of another (H_2O). A unique property of clathrates is the absence of chemical bonding, which makes it possible to separate them relatively easily.

When methane hydrates are warmed or depressurized, it will revert back to water and natural gas. 1cf of gas hydrates could hold as much as 170 ft^3 of gas.

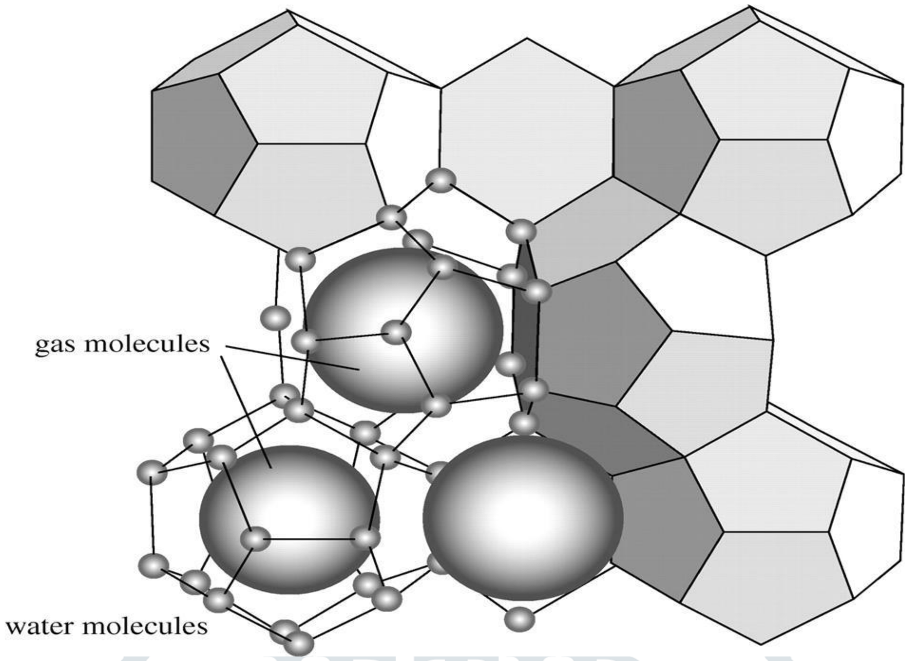

Figure1: Structure of Gas Hydrate Clathrate Compound

Hydrate deposits generally occur in two types of settings: on submarine continental slopes and in deep ocean floor sediment where temperature and pressure conditions are suitable for their formation. The majority of the gas hydrates supply is found over 1,600 feet below the sea's surface. Methane that forms hydrate can be both biogenic (created by biological activity in sediments) and thermogenic (created by geological processes deeper within the earth).

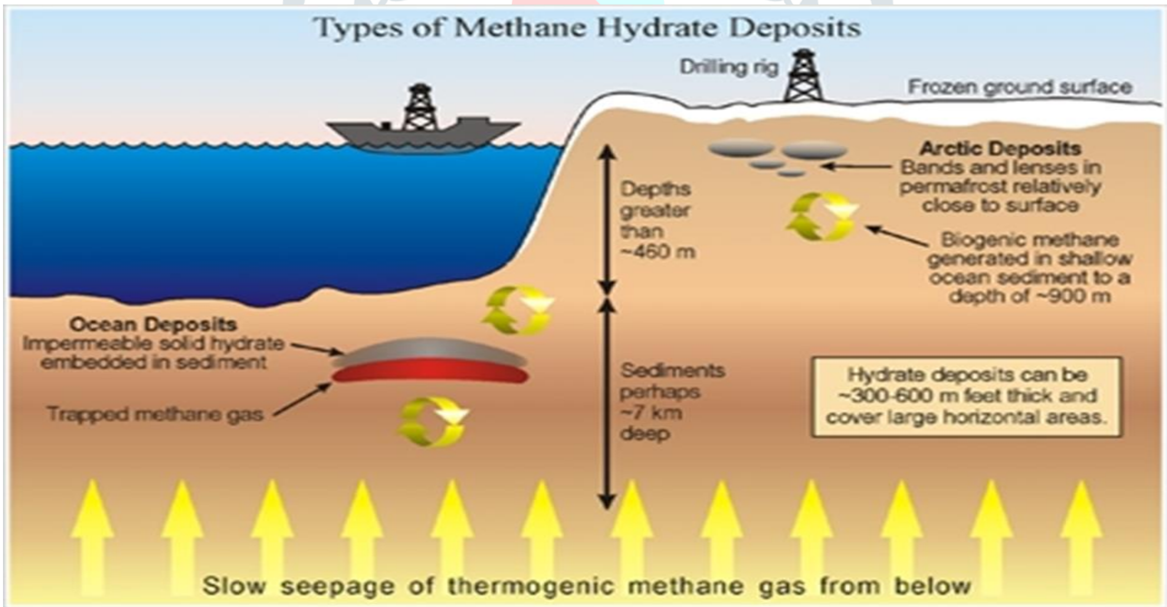

Figure2: Types of Methane Hydrate Deposits

Gas hydrates are important for three reasons:

- They may contain a major energy resource
- It may be a significant hazard because it alters sea floor sediment stability, influencing collapse and land sliding
- The hydrate reservoir may have strong influence on the environment and climate, because methane is a significant greenhouse gas.

III. PROBLEMS ENCOUNTERED DURING DRILLING

With the increase of drilling operations in marine environment after 1970s, it was observed that gas hydrate formation in borehole and its plugging of subsurface well control equipment is commonly observed in offshore drilling. For this reason, the drilling of gas hydrate reservoirs was considered as a big problem. However, the issue is not related to the sediments including gas hydrates. It is directly related to gas hydrate formation. Even though gas and gas hydrate are not observed within gas hydrate stability zone, the gas coming from the deeper sediments forms gas hydrates inside the wellbore and subsurface equipment. Mainly, the poor cementing of casings and poor gas hydrate inhibition on subsurface well control equipment caused the problems during the drilling of deep marine sediments. Especially, blow-out preventers (BOP) could not shut off due to gas hydrate formation inside it as kick was observed in high pressures. While exploring for conventional oil and gas reservoirs in deep sea sediments, gas might form gas hydrates and plug BOP because it is commonly seen in offshore environment if there is no or less inhibitor inside BOP or other surface equipment.

There is a typical thought that drilling gas hydrate reservoirs is very unsafe. Some of these risks are listed below:

- Choke and Kill-line plugging: This causes difficulty in the use of the lines during well circulation
- Plug formation at or below the blow out preventers (BOP): Well-pressure monitoring below the BOPs becomes impossible or difficult
- Plug formation around the drillstring in the riser, BOPs or casing: Makes the drillstring movement a problem
- Plug formation between the drillstring and BOPs: This causes problems in the full closure of the BOPs when necessary
- Plug formation in the ram cavity of the BOPs: Causes difficulty in opening the BOPs fully.
- Slope failure risk due to sudden gas hydrate dissociation. The dissociation of the Gas Hydrates involves the following technical problems:
    1. Loss of Structural Integrity of the Hole: The Gas which is released from the GHBF may decrease the Density of the Drilling Fluid, which makes the changes in Mud Rheology leads to decline in Hydrostatic Pressure below Formation Pressure.
    2. Loss in Strength of the Structure: Hydrate dissociation will change the Chemical and Physical properties of the Wellbore (Porosity, Permeability).

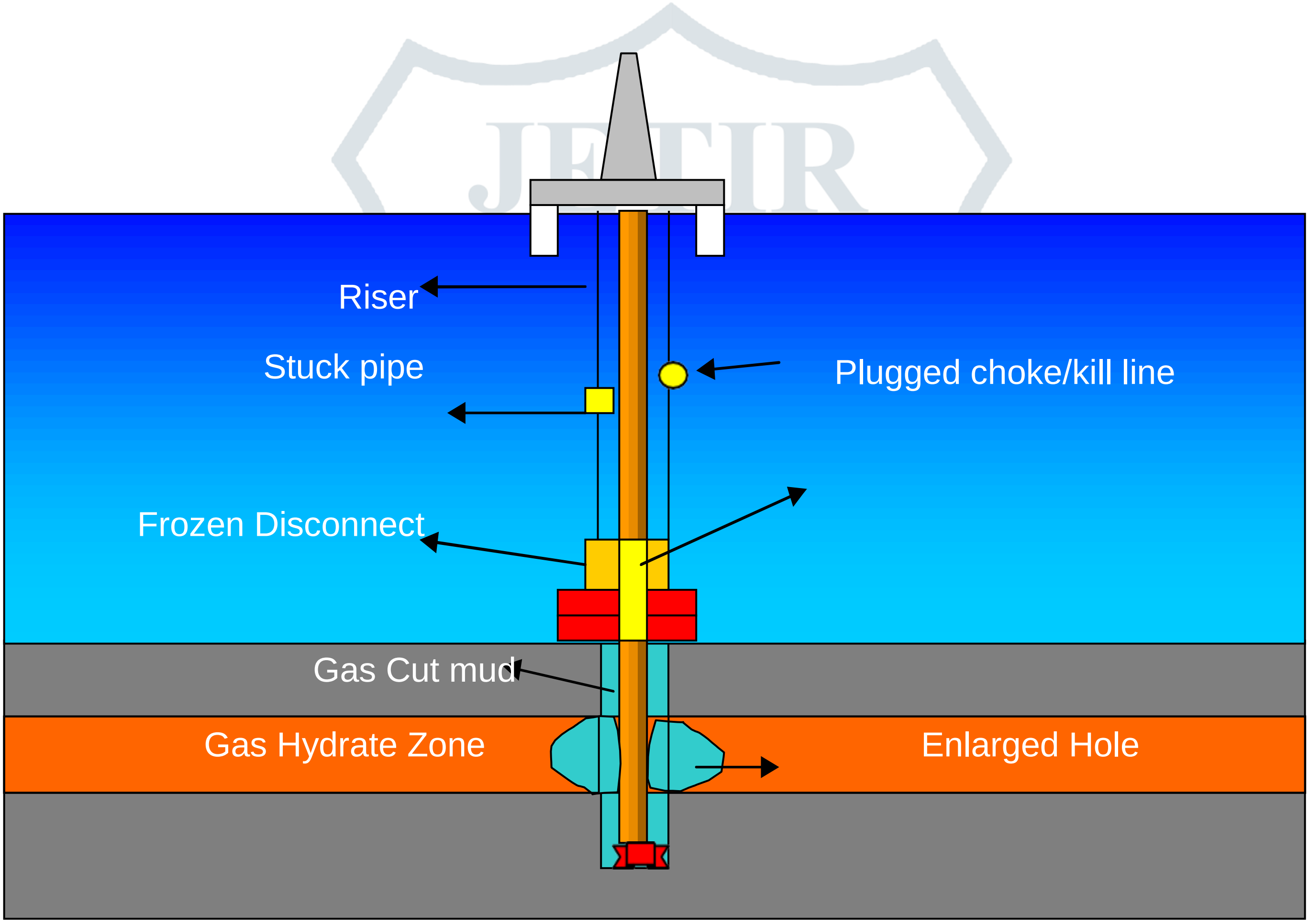

Figure 3: Pictorial representation of the problems encountered during drilling through gas hydrate zones

IV. NEW DRILLING SOLUTIONS (MENTIONED IN LITERATURE)

There is a very good possibility of hydrates forming in the wellhead, BOPs, choke line and kill line during a drilling operation, hence the importance of proper assessment of the drilling conditions and environment before proceeding to deepwater or offshore drilling. The important parameters needed for this assessment include temperature, pressure conditions, gas compositions, drilling mud properties and fluid phase compositions. The temperature and pressure conditions for most drilling operations can be predicted with respect to the depth. Many hours or days may elapse during which the well will not be circulated, allowing the wellbore temperatures to approach static gradients. Gas Hydrate Inhibitors are used after hydrate plugging in the plugging but, the below are the drilling solutions prior to hydrate formation in wellbore.

Some new technologies to consider in deepwater or offshore drilling may include:

- Managed Pressure Drilling (MPD): A process used to control the annular pressure profile throughout the wellbore. The objectives include ascertaining the downhole pressure environment limits and to manage the annular hydraulic pressure profile.

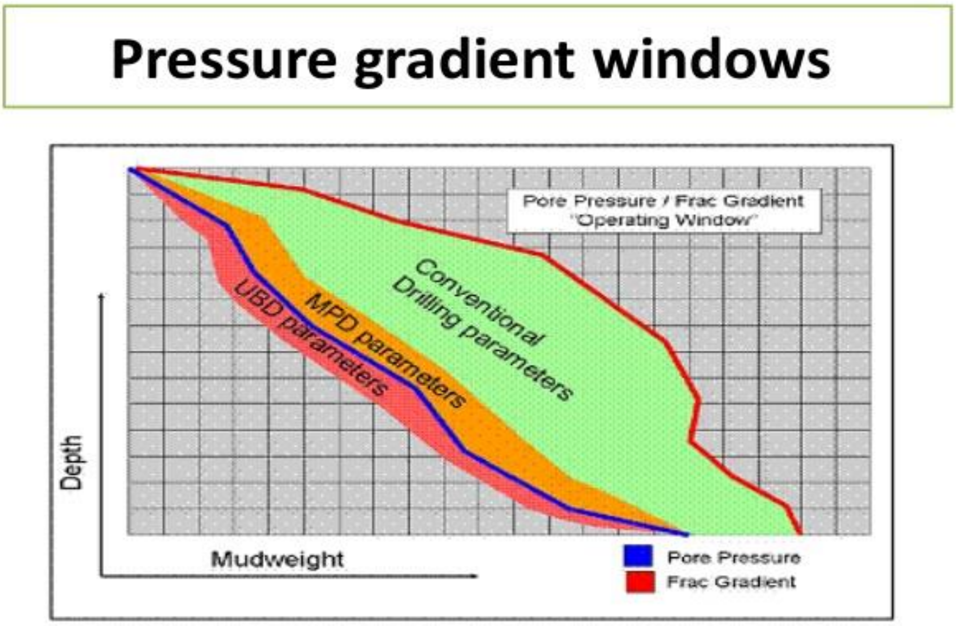

Figure4: Pore Pressure/Frac Gradient "Operating Window"

- Slim and Insulated Marine Riser: Deep sea currents and the need to insulate the riser, especially in temperate waters, indicate the applicability of the slim riser deep-water drilling technology with a surface BOP. The increased velocity of returns will allow the returns chilled by drilling into hydrates less time for heat transfer to warm the returns, thus reducing dissociation within the riser itself. Further, it is believe a 13-3/8 in marine riser may be less adversely affected by underwater currents. Drilling with a chilled mud system to maintain bottom-hole temperature (BHT) below 11ºC should be sufficient to avoid any dissociation of the hydrate or associated gas in the return riser.
- Drilling the Top Hole in Deep Water: A riserless top drilling package is applied to a batch drill process. Such a system incorporates a subsea rotating control device and a subsea choke that enables mud returns to be pressurized with pipe rotation. A subsea pump returns annulus fluids to the floating rig via a mud returns riser or flowline. Such a system is a "riserless" closed loop circulation system and offers precise wellbore pressure management in the top hole by adjusting the surface mud pump rate, applying backpressure to the annulus at the seafloor and adjusting subsea mud return pumping rate.
- Underbalanced Drilling: It is applicable to fixed rigs with surface BOPs and floating rigs with subsea or surface BOPs. The real time temperature and pressure monitoring used in the underbalanced drilling could be particularly useful in drilling through hydrates.
- Drilling With Casing (DWC): It is a one-trip casing drilling technology that tries to avoid pulsating the fragile and frozen wellbore unnecessarily. A robust casing could be one-trip set and cemented to a sufficiently deep depth to minimize the risk of seafloor collapse from the temperature, pressure and chemical quasi-mining process of producing the methane hydrates over time. The circulation f cold drilling mud could assist in absorbing the heat released by the setting of the cement.
- Logging While Drilling (LWD): The main reason for LWD is that gas hydrates are very sensitive to pressure and temperature changes so coring operations might not be enough to determine exact reservoir properties of gas hydrates. Thus, LWD is advantageous.

V. LIMITATIONS OF BOTTOM SIMULATING REFLECTOR (BSR)

Bottom Simulating Reflector (BSR) events typically occur at a depth of between 200 and 600m beneath the seafloor based on seismic reflection data. These unusual reflections cross cut sedimentary layer reflectors and are parallel to the seabed. Many people have interpreted the BSR to be generated at the transition between sediments containing a variable amount of solid gas hydrate above and sediments containing a small volumetric fraction, typically a few percent of free gas below. Gas hydrate related BSR should consequently lie at depths that closely correspond to base of the gas hydrate stability zone (GHSZ). The GHSZ is controlled both by temperature and pressure, as well as by chemical conditions.

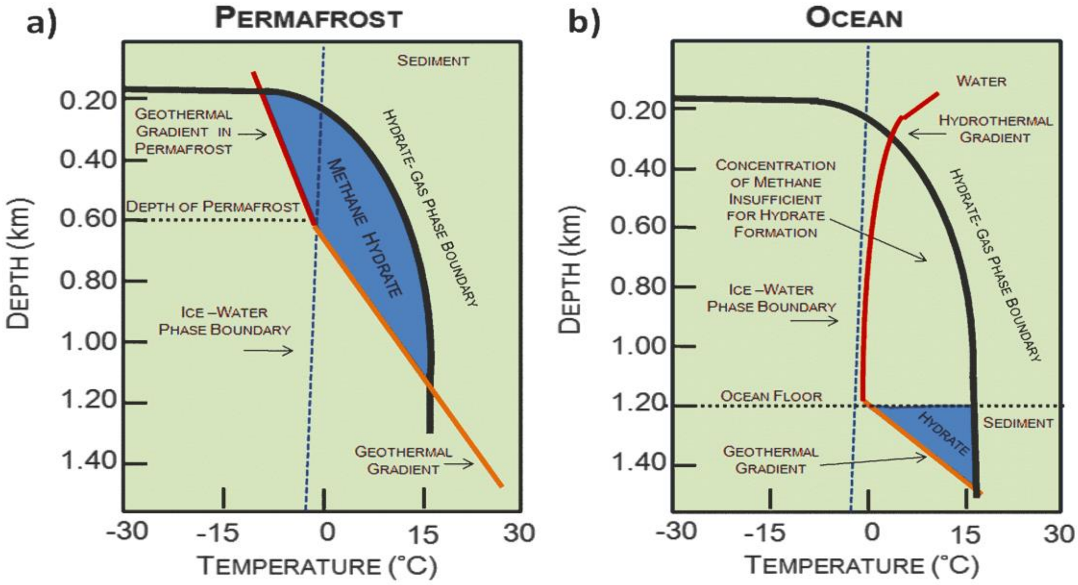

Figure5: Gas Hydrate Stability Zone Diagram

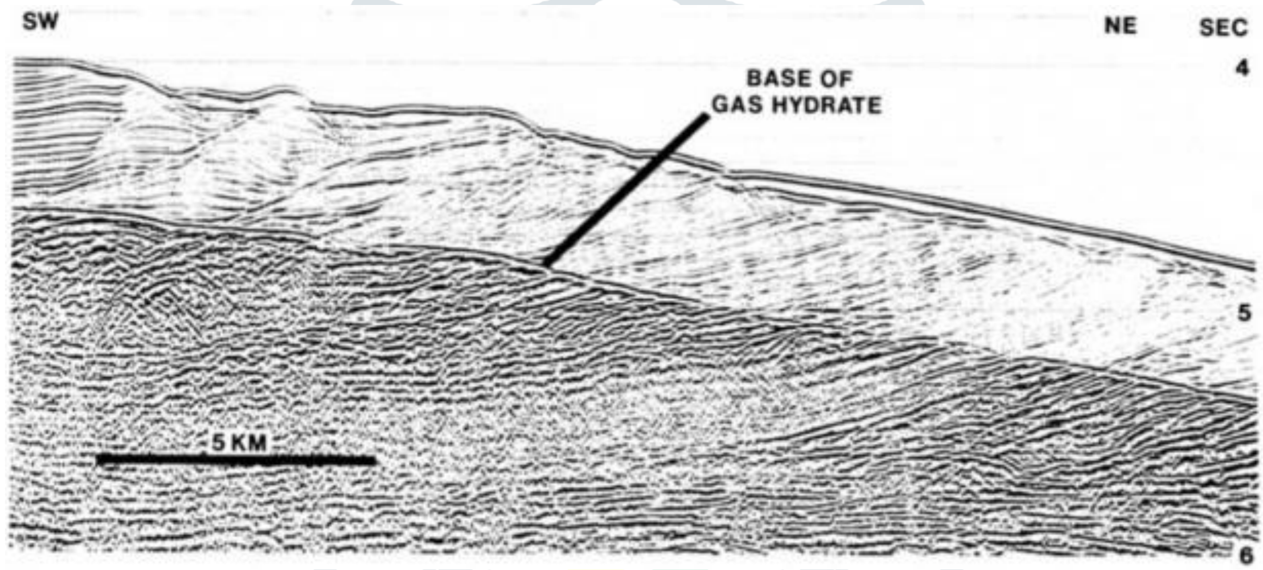

Figure6: Bottom Simulating Reflector

A BSR can exist without any evidence for gas hydrates and alternatively, gas hydrates were recovered where no BSR is present. These results, among others, based upon ground truth, have leaded some people to reconsider the interpretation of the BSR. Many alternative explanations have been proposed to account for the BSR, including artifacts of the recording equipment, sedimentary changes or unconformities, velocity changes due to opalization or multiple arrival of a velocity contrast in the water layer. However, when the depth of the BSR reflection approximates the predicted limit of the GHSZ, most people still consider that the BSR is related to hydrate formation.

During further explanation into the analysis of the complexity of ‘BSR occurrence areas’, some people have identified superimposed BSR. Cases have reported the occurrence of double BSR on the margin west of Norway. And they suggested that ‘the upper double BSR may mark the top of gas hydrates and the lower double BSR may represent a relict of former changes of the gas hydrate stability field from glacial to interglacial times or base of gas hydrates with a gas composition including heavier hydrocarbons.’ Some evidence had marked the origin of a double BSR on the Nankai margin off Japan. They interpret the uppermost BSR as an active methane hydrate-reflected reflector and the deepest BSR as an residual hydrate-related reflector. This could record a recent migration of the base of the methane hydrate stability zone from the deepest BSR to the upper one.

VI.INTEGRATION OF SEISMIC WHILE DRILLING WITH SEISMIC WAVE ATTENUATION OF GAS HYDRATE

6.1 SEISMIC WHILE DRILLING (SWD) PRINCIPLES

From the above limitations we can understand that the analysis of BSR requires further investigation as the reflection strategy was not 100% accurate for detecting Gas Hydrate Zones. In concept, any type of mechanical vibration that is introduced into the Earth can be used as a seismic wave field to illuminate and image subsurface geology. Seismic imaging does not always have to be done with controlled, sophisticated sources such as air gun arrays, vibrators or shot hole explosives. One unique mechanical vibration that illustrates the principle of seismic imaging without the use of a conventional seismic source is the repetitive Earth impulses that are created by the drill bit as a well is being drilled to reach a geologic target. Drill-bit seismic technology was a topic of rather intense research and development in the 1980s and 1990s, and the application should not be forgotten.

Two SWD techniques have been used by the industry:

- Drill bit-SWD, which consists in recording the seismic noise generated by a rock bit under effective drilling on any number of surface seismic sensors. This technique have been used steadily since 1986;
- Vertical Seismic Profile While Drilling (VSP-WD), which consists in recording the seismic signal generated by a surface seismic source on seismic sensors integrated inside the downhole Borehole Assembly (BHA). This emerging technique has been operated since year 2000 about, mainly by Schlumberger.

The first SWD work was done where the drill bit was the source. But, today, most drilling is done with PDC bits, and the PDC bit is not an adequate source. It's too quiet. The roller bit was a good source. It crushed the rock so it made more noise. The PDC bit shears the rock, so runs very quietly.

Technology International Inc. of Kingwood, Tex., has developed a breakthrough borehole imaging system that is nearly commercial, according to the US Department of Energy, which is sponsoring the project. By pushing the limits of seismic-while-drilling technology, the patent-pending SeismicPulser system provides more accurate geosteering for oil and gas discoveries, facilitating field development and improving well economics, DOE's Fossil Energy Office (FEO) said. It said drill bit SWD technology uses a downhole acoustic source and receivers at the surface to create real-time images that allow operators to "see" ahead of the drill bit. The new technology is based on what's called a SeismicPulser. It provides for an otherwise high frequency impulse source to generate low frequencies. With low frequencies, you can transmit from great depths to the surface.

Hydraulic pulsers demand a large amount of the available hydraulic energy at the bit, which causes the bit to drill slower. The SeismicPulser, however, uses less than 15 hydraulic horsepower. It generates high voltage downhole, which is used to pulse a sparker. The sparker lifts the SeismicPulser technology and produces low frequencies that can be transmitted to the surface. The SeismicPulser system was developed to withstand high-pressure, high-temperature (HPHT) environments in deep onshore and offshore deepwater wells that require special imaging technologies, DOE said. DOE said no drill bit SWD system available currently has the new system's full capabilities. It said the system, which is built into or attached to the drillstring, emits broadband low-frequency sounds that, based on seismic calculations, can be transmitted to surface receivers from depths beyond 30,000 ft. Project managers have indicated that SeismicPulser is the only system that meets the requirements of those companies planning to drill HPHT wells to as deep as 35,000 ft in ultradeep water, according to DOE. It said SeismicPulser provides accurate drill bit location relative to predrilling reservoir models and gives the operator real-time images roughly 1,000 ft ahead of the drill bit, all without interfering with normal drilling operations. The system costs less than conventional vertical seismic profiling systems and increases safety and cost savings by detecting unexpected increased pore pressure ahead of the bit, DOE said. It also provides new operational capabilities by allowing operators to visualize and steer towards more optimal targets when drilling deep formations, it added. DOE said funding for the project came from FEO's oil and gas program. Field testing was performed at the University of Texas's Devine seismic test site and DOE's Rocky Mountain Oilfield Testing Center near Casper, Wyo. The project was managed by the FEO's National Energy Technology Laboratory.

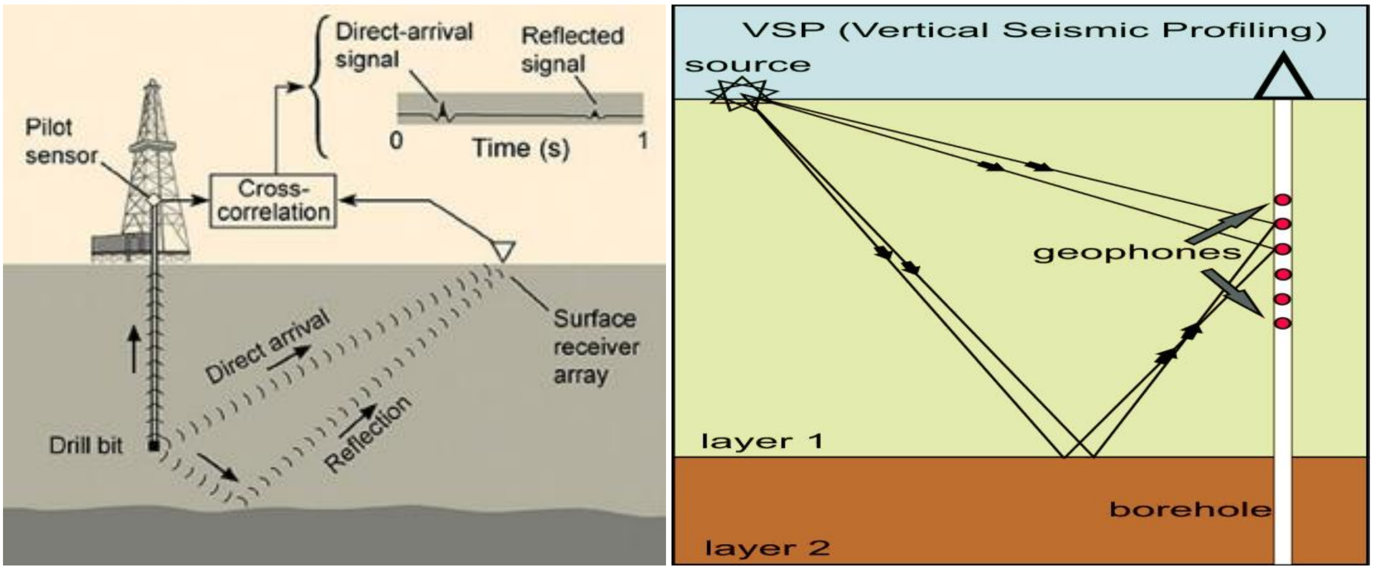

Figure7: SWD Techniques (Drill bit-SWD & VSP-SWD)

6.2 SEISMIC WAVE ATTENUATION OF GAS HYDRATE

Seismic waves are waves of energy that travel through the Earth's layers, and are a result of earthquakes, volcanic eruptions, magma movement, large landslides and large man-made explosions that give out low-frequency acoustic energy. Many other natural and anthropogenic sources create low-amplitude waves commonly referred to as ambient vibrations. The propagation velocity of the waves depends on density and elasticity of the medium. Velocity tends to increase with depth and ranges from approximately 2 to 8 km/s in the Earth's crust, up to 13 km/s in the deep mantle. Earthquakes create distinct types of waves with different velocities; when reaching seismic observatories, their different travel times help scientists to locate the source of the hypocenter. In geophysics the refraction or reflection of seismic waves is used for research into the structure of the Earth's interior, and man-made vibrations are often generated to investigate shallow, subsurface structures.

Elastic-wave data collected around the world in sediments with methane hydrate point to significant velocity increases due to the presence of the hydrate in the pores. This effect can be easily understood if we recall that gas hydrate is a solid as opposed to brine or gas. By filling the pore space, gas hydrate acts to reduce the porosity available to the pore fluid and, increase the elastic moduli of the solid frame. However, it is difficult to reconcile this effect with more recent observations that the attenuation of elastic waves grows with increasing gas hydrate concentration.

Indeed, intuitively, one would expect that the stiffer the rock, the smaller the relative elastic energy losses per cycle and the smaller the attenuation. Measurements in many sediments support this intuition. For example, Attenuation increases with increasing porosity and clay content, while the velocity behaves in an opposite way. This intuition, combined with quantitative modeling, suggested reduced absorption as a possible seismic attribute for methane hydrate detection. However, the facts are persistent. Unexpectedly large attenuation in sediments with gas hydrates has recently been observed at different geographical locations, in different depositional environments and at different frequencies. In 1999, Guerin et al. presented qualitative evidence of dipole waveform attenuation in the hydrate-bearing sediments in the Outer Blake Ridge off the U.S. east coast. Sakai (1999) noted that the shear-wave VSP signal may be strongly attenuated in a Mallik well within the methane-hydrate interval. Wood et al. (2000) observed increased attenuation of seismic waves at the same location. Guerin and Goldberg (2002) used monopole and dipole waveforms to quantify compression and shear wave attenuation. They reported a monotonic increase in both with increasing hydrate saturation. Pratt et al. (2003) reported an increase in attenuation in the Mallik hydrate reservoir between two methane hydrate wells during cross-hole experiments in the 150-500 Hz frequency range. Anomalous absorption has been observed in the Nankai Trough methane hydrate reservoir offshore Japan in the same seismic frequency range. We have no reason to question the validity of these field data and, therefore, concern ourselves with the task of establishing a plausible quantitative physical explanation and of determining in which situations increased attenuation can be expected in methane hydrate reservoirs.

Elastic-wave amplitude losses in a methane hydrate reservoir grow as hydrate concentration increases because the hydrate in the pores acts to increase the elastic moduli of the rock. e in the pores acts to increase the elastic moduli of the rock. This increase results in increasing elastic heterogeneity which encourages pore-fluid crossflow between stiff and soft domains of the rock, triggered by the passing wave. The viscous energy losses due to this wave induced fluid crossflow partly responsible for the elastic wave attenuation. Scattering of the seismic energy is also amplified by elastic heterogeneity and may add to the amplitude loss. In short, attenuation in sediment with hydrate is due to self-induced elastic heterogeneity.

6.3 SWD AND SEISMIC WAVE ATTENUATION INTEGRATION

With the above principles mentioned above for Seismic wave attenuation of Gas hydrate, it can be clearly understand that using seismic wave attenuation velocities of Gas hydrate it can be clearly identify the Gas Hydrate formations. With Seismic While Drilling applying in wells drilling through Gas Hydrates, it can be used as a tool to detect GHBZ about 1000-3000ft prior to the entering. When we can detect Gas hydrate zones in prior, it is easier to take necessary precautionary methods in drilling operational parameters, so that it reduces loss in economy and rig time. It can also be used as depth correlation checker for BSR, which gives additional support to confirm the hydrate zones.

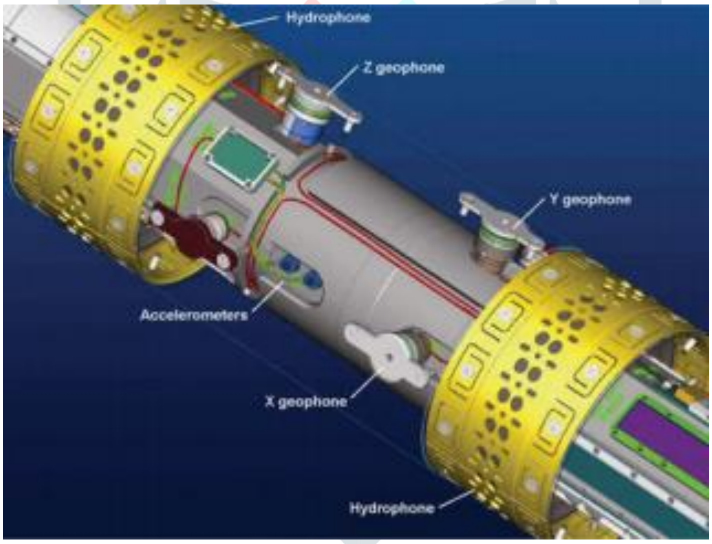

Figure8: SWD Assembly with downhole Seismic Source

VII. GAS HYDRATES AS FUTURE ENERGY SOURCE

Rather than thinking Gas Hydrate formations as a risk during, with the unbalanced energy supply Industry was changing its perspective towards Gas Hydrates a potential source for exploring and producing Natural Gas from those Zones with controlled drilling and production operations.

Initial work in India on Gas Hydrates as energy resource, was done by GAIL and NIO. In 1995 an expert committee realized the potential of gas hydrates in India.

Gas hydrate exploratory activities/ research in India is being steered by the Ministry of Petroleum & Natural Gas under National Gas Hydrate Program (NGHP) which was initiated in 1997 with participation from Directorate General of Hydrocarbons (DGH), National E&P companies (Oil and Natural Gas corporation Ltd, GAIL India Ltd, Indian Oil Corporation & Oil India Ltd) and National Research Institution (National Institute of Oceanography, National Geophysical Research Institute and National Institute of Ocean Technology). Steering Committee is headed by Secretary, P&NG with Joint Secretary (E) as convener. The Technical Committee is chaired by DG, DGH and has participation from all National Oil Companies (NOC) like OIL, ONGC, GAIL, IOCL, and National Institutes like the NGRI, NIO & NIOT. The NGHP was restructured in the year 2000.

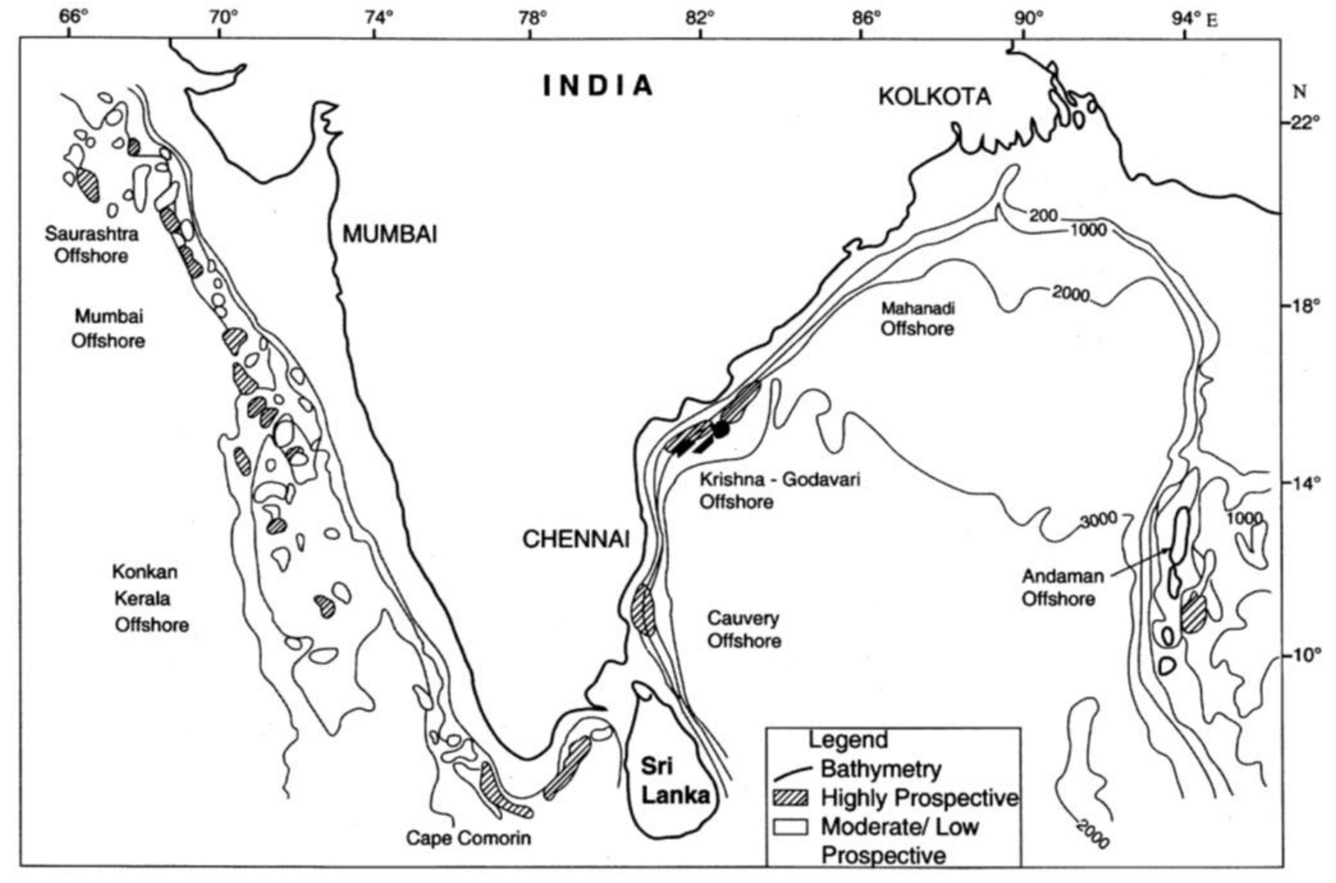

Figure9: Gas Hydrate Accumulated Regions along Indian Continental Shelf

7.1: CURRENT STATUS

a) NGHP carried out the expedition-01 in 2006. The presence of significant quantities of Gas Hydrate has been established in the KG, Mahanadi and Andaman basins.
b) NGHP Expedition 02 aims at identifying sites which would ideally have:

- Sand dominated gas hydrate occurrence
- Reasonably compacted sediments
- Occurrence of free gas below the gas hydrate stability zone

c) NGHP Expedition-02 has been approved by the Steering Committee of NGHP. NGHP Expedition 02 consists of LWD (Logging while drilling), Coring and wire line lo9gging program at about 20 sites (40wells) in the deep water KG & Mahanadi basins. The cost of NGHP Exoedtion-02 shall be shared by OIDB (50%), ONGC (20%), OIL (10%), GAIL (10%) and IOCL (10%).
d) The drill ship CHIKYU has commenced operations under the NGHP Exp-02 on the 4th of March 2015. Till the 31st march 2015 Logging While Drilling (LWD) has been completed at 13 wells. The NGHP Expediton-02, including the coring leg, is expected to be completed by the 31stjuly 2015.
e) Expedition 03 aims at carrying out pilot production testing of at least one site in the Indian deep-water environment. However, the execution of Expedition-03 depends on the success of NGHP Expedition-02.

VIII. CONCLUSION

The industry solution has always been to avoid gas hydrate bearing zones while drilling. This is in a bid to avoid the dangers associated with drilling through these formations. Some of the notable problems include wellbore stability, gas cut mud, and seafloor stability amongst others. Based on this research, we have been able to suggest some possible ways of drilling through gas hydrate formations and avoiding some of the afore-mentioned problems.
Other than BSRs, there are other seismic attributes that correlate well with hydrates are Reflection Strength, Instantaneous Frequency and Seismic Blanking. As lot of investigation is going on and the Seismic Wave Attenuation properties are developing it is easier to understand the acoustic properties of Gas Hydrates, which in turn helps to detect the GHBZ.
For Conventional Hydrocarbon wells and also for Natural Gas Hydrate production wells Seismic While Drilling can be used a tool to identify and also used as depth checker for BSR Data.
Based on the increasing need for energy, more wells are being drilled in areas of deeper waters. These areas have provided cores which indicate the presence of gas hydrate. The need to study and understand the properties of gas hydrate lies in a number of factors. Gas hydrates contain an enormous amount of energy which is anticipated to provide alternative sources of energy in the near future. The presence of gas hydrate in deeper offshore areas emphasizes the need to deal with them as we try to harness the hydrocarbon found beneath these hydrate zones. Recently, the effect of gas hydrate on the environment and most specially on global warming has also brought the topic more research consideration.

Figure10: Gas Hydrate Sample

With the consumption of conventional gas reservoirs and development of drilling, logging and coring technology, many countries and scientists have focused on the gas hydrate explorations because there are enormous gas reserves in gas hydrates. Although there are many challenges in gas hydrate exploration, recently many successful gas hydrate wells have been drilled in marine environment and permafrost. Almost one decade ago, it was considered that drilling in gas hydrate reservoirs was quite risky. However, recent drilling expeditions in marine environment and permafrost show that gas hydrate does not dissociate immediately and most of the drilling problems faced were similar to those observed in conventional drilling operations. It is obvious that special cares should be taken to maintain gas hydrate reservoirs as stable as possible with drilling fluid selection and cement composition selection. Hence, compared to production technology in gas hydrates, drilling technology is much more developed in gas hydrate well drillings.

Finally it is very likely that the continuous understanding of gas hydrate from a drilling perspective could actually improve the success in producing the enormous resource trapped in these formations.

References

1. Makogun, Y.F., *Hydrates of Hydrocarbon*, PennWell, Tulsa, Oklahoma.

2. Evaluation of drilling parameters in gas hydrate exploration wells, Şükrü Merey, Batman University, Department of Petroleum and Natural Gas Engineering, Batman, Turkey, published in Journal of Petroleum Science and Engineering.

3. Drilling of gas hydrate reservoirs, Sükrü Merey, Middle East Technical University, Department of Petroleum and Natural Gas Engineering, Ankara, Turkey, published in Journal of Petroleum Science and Engineering.

4. Drilling through Gas Hydrate Formations: Possible Problems and Suggested Solutions, a Thesis by Afolabi Ayoola Amodu, presented to Texas A&M University, USA.

5. https://www.usgs.gov/centers/cersc/science/results-india-national-gas-hydrate-program-expedition-02

6. Oil Industry Development Board, Ministry of Oil and Natural Gas, Government of Inida.

7. https://www.usgs.gov/centers/cersc/science/results-indian-national-gas-hydrate-program-expedition-01

8. Gas Hydrates Research Programs: An International Review Final Report, Jorge Gabitto Maria Barrufet Prairie View A&M State University Texas A&M University Department of Chemical Engineering Petroleum Engineering Department, 2010.

9. Methane Hydrates and the Future of Natural Gas Carolyn Ruppel (cruppel@usgs.gov) Gas Hydrates Project U.S. Geological Survey, Woods Hole, MA.

10.https://www.thehindu.com/sci-tech/energy-and-environment/In-a-first-natural-gas-hydrates-discovered-in-the-Indian-Ocean/article14509657

11. https://www.ogj.com/articles/ogfj/print/volume-14/issue-2/features/india-s-gas-hydrates.html

12. http://www.dghindia.org/index.php/

13.https://www.aapg.org/career/training/in-person/distinguished-lecturer/abstract/Articleid/32854/indian-national-gas-hydrate-program-expedition-02-technical-contributions

14. https://en.wikipedia.org/wiki/Methane_clathrate

15. https://science.howstuffworks.com/environmental/energy/natural-gas-hydrates.htm

16. https://wiki.seg.org/wiki/Hydrates

17. http://www.drillingcontractor.org/seismic-while-drilling-where-is-it-heading-1686

18. https://www.rocksolidimages.com/pdf/ICDvorkin08.pdf

19. New seismic-while-drilling systems may help operators navigate complex well paths - Drilling Contractor

20. Subsurface Sediment Mobilization - Google Books

21. Advances in Geosciences: Ocean Science - Jianping Gan, W.-H. Ip - Google Books

22. https://www.moes.gov.in/programmes/gas-hydrates

23. https://en.wikipedia.org/wiki/Seismic_wave

24. https://www.ogj.com/home/article/17221668/seismicwhiledrilling-technology-advance-hailed

25. https://www.tandfonline.com/doi/abs/10.1071/ASEG2013ab045